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INFLUENCE OF RICE VARIETY AND PLANT SPACING ON WEED SUPPRESSION UNDER AEROBIC SOIL CONDITION

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By

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

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

INFLUENCE OF RICE VARIETY AND PLANT SPACING ON WEED SUPPRESSION UNDER AEROBIC SOIL CONDITION

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August 2013

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Faculty : Agriculture

This study comprised of two sets of experiments. The plant house and field trials were conducted at MARDI Bertam Rice Research Station in Seberang Perai, Penang. First experiment was conducted in plant house and it was repeated in the field. The second experiment which also repeated was conducted both at experimental field. These studies began in December 2008 and ended in March 2011. Weeds are the greatest constraint in aerobic rice cultivation due to lack of water standing to suppress weed. Therefore, by adoption of competitive rice varieties and the optimum plant spacing could reduce yield losses due to weed competition.

The objectives of the first experiment were to evaluate the competitive ability of five rice varieties (AERON 1, AERON 4, M9, MR211 and MR 220CL2) against weeds under aerobic rice systems, and thus determining the suitable variety for aerobic rice

cultivation. The above five rice varieties were evaluated to determine their performance under two weeding regimes (weedy and weed free condition). The experimental units were kept unweeded (weedy treatment) and weed free (weed free treatment) throughout the growing season. Manual weeding and the application of recommended herbicides (Sofit and Satunil) were conducted to control weeds in weed free treatments. AERON 1 had resulted in the lowest weed dry weight and weed density while the highest was observed in MR211, in both plant house and field experiments. Sixteen weed species had infested the experimental unit in the plant house and field experiments. In weed composition, the sum dominance ratio (SDR) value showed that grasses infested at the highest percentage as compared to those of sedges and broadleaves (resulted in minor infestation). *Leptochloa chinensis* was the most dominant weed in plant house while in field was *Echinochloa colona*. Weed competition gave negative effect on selected parameters of growth and development [plant height, tiller number and SPAD value], grain yield and yield components (filled grain panicle^{-1}, sterility percentage and thousand grain weight). AERON 1 produced the highest grain yield which 2.02 t ha^{-1} and 1.79 t ha^{-1} in plant house and field experiment, respectively while MR211 produced the lowest yield. The yield production of M9, MR220 MCL2 and especially MR211 were adversely affected by weeds and possibly by aerobic condition. Relative yield loss was higher in plant house (57.1 % to 74.8%) as compared to those in the field (53.1% to 70.9%). The lowest percentage relative yield loss was obtained at AERON 1 and this showed that AERON 1 was the most competitive variety against weeds as it yielded the lowest weed dry weight (better weed suppressive ability) and relative yield loss (weed tolerance) and it had high grain yield.

The objective of second experiment was to determine the best plant spacing to achieve maximum yield and better weed suppression under aerobic condition. From previous study, AERON 1 had been chosen as planting material as it produced the highest grain yield and the lowest relative yield loss. The second experiment consist of five plant spacing namely 10 x 10 cm, 15 x 15 cm, 20 x 20 cm, 25 x 25 cm and 30 x 30 and was repeated in the second trial with the slightly modification of treatment with spacing of 15 x 15 cm, 15 x 20 cm, 20 x 20 cm, 20 x 25 cm and 25 x 25 cm. Both trials were tested under two weeding regimes (weedy and weed free condition). The lowest weed dry weight was produced by the closest plant spacing (10 x 10 cm in first trial and 15 x 15 cm in second trial). Similar pattern was observed in weed density (no. m^{-2}). Grasses was the most dominant weeds in both trials, followed by sedges and with smaller amount of broadleaves. In the first trial, rice field was infested with 12 weed species with the most dominant weed was *Echinochloa colona*. The second trial was dominanted by *Leptochloa chinensis* with 22 weed species observed. Mean of grain yield was highest at closest spacing of 10 x 10 cm (2.55 t ha^{-1}) in first trial, and in the second trial was 1.85 t ha^{-1} of yield in 15 x 15 cm spacing. Relative yield loss due to weed competition was ranging from 36.1 % to 54.9 % in the first trial, and with the range of 50.7% to 57.2% in the second trial. The best plant spacing suggested from this study was 10 x 10 cm spacing or 15 x 15 cm for higher yield and better weed suppression.

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

PENGARUH VARIETI PADI DAN JARAK TANAMAN TERHADAP PENYEKATAN RUMPAI DALAM KEADAAN TANAH AEROBIK

Oleh

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Kajian ini terdiri daripada dua set ekperimen. Percubaan rumah tanaman dan ladang dijalankan di Stesen Penyelidikan MARDI, di Seberang Perai, Pulau Pinang. Ekperimen pertama dijalankan di rumah tanaman dan diulangi di ladang. Manakala eksperimen kedua yang mana kedua-duanya dijalankan di ladang. Kajian ini bermula pada Disember 2008 dan berakhir pada Mac 2011. Rumpai merupakan halangan terbesar dalam penanaman padi aerob disebabkan oleh ketiadaan air bertakung untuk menghalang pertumbuhan rumpai.

Objektif eksperimen pertama adalah untuk menilai kebolehansaingan lima jenis varieti padi terpilih (AERON 1, AERON 4, M9, MR211 dan MR 220CL2) terhadap rumpai dalam sistem aerobik dan seterusnya mengenalpasti varieti yang sesuai untuk penanaman secara aerobik. Lima jenis varieti padi telah dinilai keupayaannya dalam dua keadaan

rawatan iaitu berumpai dan tidak berumpai. Unit-unit eksperimen ini dibiarkan tidak dirumpai (rawatan berumpai) dan tiada rumpai (rawatan bebas rumpai) sepanjang musim penanaman. Merumpai secara manual dan penggunaan racun herba yang disarankan (Sofit dan Satunil) dilakukan bagi mengawal rumpai dalam rawatan tiada rumpai. Eksperimen pertama menunjukkan AERON 1 memberikan berat rumpai kering dan kepadatan rumpai yang paling sedikit dan MR211 memberikan berat rumput kering yang tertinggi, dalam kedua-dua keadaan rumah tanaman dan ladang. Terdapat enam belas spesies rumpai di kedua-dua rumah tanaman dan ladang. Untuk komposisi rumpai, nilai jumlah nisbah dominan menunjukkan rumpai jenis rumput menyerang pada peratusan yang tinggi berbanding rusiga dan rumpai berdaun lebar (infestasi rendah). *Leptochloa chinensis* adalah rumpai dominan di dalam rumah tanaman, manakala di ladang adalah *Echinochloa colona*. Persaingan dengan rumpai memberikan kesan negatif terhadap pertumbuhan dan pengembangan pokok padi [tinggi pokok, bilangan anak bilah dan nilai (SPAD)] beserta hasil padi dan komponen hasil (biji berisi per tangkai, peratusan hampa dan berat seribu biji). AERON 1 mengeluarkan hasil purata yang paling tinggi iaitu 2.02 tan per ht dan 1.79 tan per ht masing masing dalam rumah tanaman dan ladang manakala MR211 memberikan hasil terendah. Kehilangan hasil secara relatif dalam rumah tanaman adalah lebih tinggi (57.1% hingga 74.8%, berbanding di ladang (53.1% hingga 70.9%). AERON 1 memberikan peratusan kehilangan hasil secara relatif terendah dan ini menunjukkan AERON 1 adalah varieti yang paling kompetitif terhadap persaingan rumpai sebagaimana ia menunjukkan berat kering rumpai yang terendah (penekanan rumpai yang lebih baik) dan kehilangan hasil secara relatif (toleransi terhadap rumput) serta mengeluarkan hasil yang lebih tinggi.

Objektif kajian kedua adalah untuk mengenalpasti jarak tanaman yang terbaik untuk mencapai hasil yang optimum dan pengurangan rumpai yang lebih baik dalam keadaan aerobik. Berdasarkan keputusan kajian sebelumnya, AERON 1 telah dipilih untuk dikaji dalam kajian ini kerana mengeluarkan hasil padi yang tinggi dan menunjukkan kehilangan hasil secara relatif yang rendah. Rawatan untuk percubaan kedua terdiri daripada lima jarak tanaman iaitu 10 x 10 cm, 15 x 15 cm, 20 x 20 cm, 25 x 25 cm dan 30 x 30 cm, dan telah diulang pada percubaan kedua dengan sedikit perubahan pada jarak tanaman iaitu 15 x 15 cm, 15 x 20 cm, 20 x 20 cm, 20 x 25 cm dan 25 x 25 cm. Kedua-dua percubaan yang diuji dalam keadaan keadaan berumpai dan keadaan tidak berumpai. Berat kering rumpai yang paling rendah dihasilkan oleh jarak tanaman yang paling dekat iaitu 10 x 10 cm dalam percubaan pertama dan 15 x 15 cm untuk percubaan kedua. Corak yang sama dapat diperhatikan pada kepadatan rumpai (bil. m^{-2}). Percubaan pertama diinfestasi dengan dua belas jenis rumpai yang didominasi oleh *Echinochloa colona* dan percubaan kedua diinfestasi dengan dua puluh dua jenis rumpai yang didominasi oleh *Leptochloa chinensis*. Rumpai jenis rumput adalah yang paling dominan di kedua-dua percubaan, diikuti rusiga dan sejumlah kecil rumpai berdaun lebar. Purata hasil menunjukkan jarak tanaman 10 x 10 cm dan 15 x 15 cm mengeluarkan hasil paling tinggi iaitu masing-masing 2.55 tan per ht dan 1.85 tan per ht pada percubaan pertama dan kedua. Kehilangan hasil secara relatif disebabkan oleh persaingan rumpai berjulat daripada 36.1% hingga 54.9% dalam percubaan pertama dan 50.7% sehingga 57.2% pada percubaan kedua. Daripada kajian ini, jarak tanaman yang disyorkan adalah 10 x 10 cm atau 15 x 15 cm untuk hasil yang lebih tinggi dan pengawalan rumpai dengan lebih baik.

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I certify that a Thesis Examination Committee has met on 23 August 2013 to conduct the final examination of Norhidayati binti Sunyob on her thesis entitled "Influence of Rice Variety and Plant Spacing on Weed Suppression Under Aerobic Soil Condition" in accordance with the Universities and University Colleges 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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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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NORHIDAYATI BT SUNYOB

Date: 23rd August 2013

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DAS	Days after sowing
DF	Days to flowering
DTM	Days to maturity
IRRI	International Rice Research Institute
LSD	Least significant difference
MARDI	Malaysian Agricultural Research and Development Institute
PH	Plant height
RYL	Relative yield loss
SAS	Statistical analysis system
SDR	Summed dominance ratio
SPAD	Silicon photon activated diode
TGW	Thousand-grain weight
WC	Weed competitiveness
WD	Weed density
WDW	Weed dry weight
WSA	Weed suppressive ability
WT	Weed tolerance
cm	Centimeter
kg	Kilogram
g	Gram
ha^{-1}	Per hectare

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is considered as the most important staple food in the world as it supplies the major food requirement for more than one half of the world's population (Adigun *et al*., 2005). It provides 27% of dietary energy and 20% of dietary protein in the developing countries, and it is the primary source of income and employment for more than 100 million households in Asia and Africa (FAO, 2004). The cultivation of paddy consumes a huge amount of water as compared to other crops. More than 75% of the world's rice production comes from 79 million ha of irrigated lowland (Maclean *et al*., 2002) where about 50% out of 90% of total diverted fresh water in the world is used for production of rice alone (Barker *et al*., 1998).

Water for agricultural usage is becoming increasingly scarce (Rijsberman, 2006). The main reasons of declining fresh water in agriculture sector are diverse and location specific, include shifting to urban and industrial demand and decreasing the availability because of pollution (chemicals, salts, silts) and resource depletion (Lampayan *et al*., 2003). It is estimated that by 2025, 15-20 million ha of irrigated rice will be suffering to some degree from water scarcity (Tuong and Bouman, 2003).

In mitigating to this situation, a fundamentally different approach must be found, in example, by shifting the traditional rice production system to a new promising cultivation system called 'aerobic rice'. Aerobic rice is a new concept of growing rice in non-puddled and non flooded aerobic soil (Martin *et al.*, 2007), i.e., similar to those of wheat or maize which grown in upland condition. Aerobic rice could solve the water problem requirement as it can reduce water usage by eliminating continuous seepage and percolation that greatly reducing evaporation (Castaneda *et al*., 2004).

However, the main constraint of aerobic rice systems is the occurrence of severe weed infestation than those of transplanted irrigated and rainfed lowland rice since the direct seeded aerobic rice grows simultaneously with weed growth and thus having no 'head start' over weeds and lacks a standing water layer to suppress weeds (Moody, 1983). Weeds are the greatest yield-limiting factor to direct seeded aerobic rice, in which it contributes to about 50% of yield losses, followed by constraints of nitrogen deficiency, pest and disease (WARDA, 1996). Crops and weeds compete for belowground resources like water and nutrient while aboveground resources for light. Under drought and high temperature, plants with C_4 carbon fixation pathway (most of weeds) have a competitive advantage over plants possessing the more common C_3 pathways (rice) (Rodernburg and Meinke, 2010).

There are different methods of weed control in rice such as the preventive weed control, biological and chemical weed control. Nowadays, the usage of herbicides is the most

effective method to control weed. However, intensive herbicide usage can increase costs, pose a threat to the environment and farmers health and, it may promote the development of herbicide resistance weed (Valverde *et al*., 2000). Reducing farmers' dependence on herbicides is desirable to reduce herbicide costs and selection pressure and to delay the development of herbicide resistance in weeds. Attention had been shifted to increase the integration of non-chemical methods of weed control into the current farming systems to reduce exposure of weeds to herbicide (Mcdonald, 2003), such as cultural weed control. Cultural practices, that is by using competitive cultivar (Zhao *et al*., 2006), tillage, crop rotation, variety selection, rice seeding rate and row spacing and orientation are generally based on agronomic considerations and could be manipulated that yielding in the crop-weed interaction in the favor of crops (Roa, 2000). It was reported that rice cultivars with increased competitiveness could reduce yield losses due to weed interaction, and also it could lessen hand-weeding requirements, and lower herbicides application (Haefele *et al*., 2004). Rice varieties respond differently to competition such that tall, droopy and late maturing varieties are more productive under weed infestations that short stature and semi-dwarf early maturing types (Johnson and Jones, 1993). Plant traits such as tiller number and leaf area index have shown to confer competitiveness (Fischer et al., 2001).

Hypothetically, manipulating agronomic factors such as row and plant spacing may provide a nonchemical means for reducing the impact of weed interference on crop yield (Ghadiri and Bhayat, 2004). Since the information in Malaysia is still limited, the study about competitive ability under aerobic condition is needed in order to investigate the ability of rice varieties competing with weeds under several plant spacing. Thus, it is

envisaged that the adoption of competitive rice cultivars against weeds and the suitable plant spacing could control weed infestation and achieve optimum yield under aerobic rice cultivation.

Objectives:

The general objective of the study was to reduce weed pressure in aerobic rice through adoption of competitive variety and optimum plant density. The specific objectives were:

1. To compare the competitive ability of selected rice varieties against weed, and to identify suitable rice varieties for cultivation under aerobic soil condition.
2. To evaluate the influence of different plant spacing on weed suppression and rice yield and, to determine the optimum plant spacing for aerobic rice growing.

REFERENCES

Abouziena, H.F., Shara Faida, A.A., and El-desoki, E.R. 2008. Efficacy of cultivar selectivity and weed control treatments on wheat yield and associated weeds in sandy soils. *World Journal of Agricultural Sciences* 4(3): 384-389

Adigun, J.A., Lagoke, S.T.O., and Adekpe, J.D. 2005. Efficacy of selected herbicides for weed control in rain-fed upland rice in the Nigerian Northern Guinea Savanna. *Agricultura Tropica Et Subtropika*. Vol. 38 (3-4).

Ahmed,W.U. and Moody, K. 1980. Effect of method seeding and weed control on weed growth and yield of two rice crops grown in sequence. *Tropical Pest Management* 26: 303-308

Alford, C.M., Miller, S.D., and Cecil, J.T. 2004. Using row spacing to increase crop competition with weeds. In: Proceeding of the 4th International Crop Science Congress, Brisbane,Australia, available online at Http://www.cropscience.org.u/icsc2004/poster/2/4/1/412_ alford.htm?. Accessed on 20 November 2012

Akobundu, I.O. 1987. *Weed Science in the Tropics*. Principle and Practice Wiley, Great Britain, 522p.

Akobundu, I.O. and Fagade, S.O. 1978. *Weed problems of African rice lands*. In: Rice in Africa, pp 181-192. (ed. By Buddenhagen, I.W. and Persley, G.J.), London: Academic Press.

Akobundu, I.O. and Ahissou, A. 1985. Effect of inter-row spacing and weeding frequency on the performance of selected rice cultivars on hydromorphic soils of West Africa. *Crop Protection* 4: 71-76

Alam, M.M., Ali, M.H., Ruhul Amin, A.K.M., and Mirza Hasanuzzaman. 2009. Yield Attributes, Yield and Harvest Index of Three Irrigated Rice Varieties under Different Levels of Phosphorus. *Advances in Biological Research* 3(3-4): 132-139

Aldrich, R.J. 1984. *Weed-crop ecology: Principles in weed management*. Breton Publisher, North Scituate, Massachusetts, 465pp.

Anderson, R.L. 2005. A multi-tactic approach to manage weed population dynamics in crop rotations. *Agronomy Journal* 97:1579-1583.

Armin, M., Noormohammadi, Gh., Zand, E., Baghestani, M.A., and Darvish, F. 2007. Using plant density to increase competition ability in more or less competitive wheat cultivars with wild oat. *Asian Journal of Plant Sciences*. 6 (4): 599-604.

Atlin, G.N., Lafitte, H.R., Tao, D., Laza, M., Amante M., and Courtois, B. 2006. Developing rice cultivars for high fertility upland systems in the Asian tropics. *Field Crops Research* 97: 43-52.

Atlin, G.N. and Lafitte, H.R. 2002. *Developing and testing rice testings for water-saving systems in the tropics*. In:Bouman, B.A.M., Hengsdijk, H., Hardy, B., Bindraban, P.S., Tuong, T.P., and Ladha., J.K. (eds), Water-Wise Rice Production. International Rice Research Institute, Los Banos, 256 pp., 8-11 April.

Azmi, M. 1992. Competitive ability of barnyard grass in direct-seeded rice. *Teknologi Padi* 8: 19-25.

Azmi, M. 1995. Economic assessment on various weed control methods in direct-seeded rice fields. *Teknologi Padi* 11:35-40.

Azmi, M. 2002. Weed succession as affected by repeated application of the same herbicide in direct-seeded rice. *Journal of Tropical Agriculture Food Science* 30:151-161.

Azmi, M., Baki, B.B., Mashhor, M. 1993. *Weed communities in principal rice growing areas in Peninsular Malaysia.* MARDI Report No. 165, pp1-16.

Azmi, M. and Baki, B.B. 2007. Weed flora in landscapes of the Muda rice granary in the new millennium: a descriptive analysis. *Journal of Tropical Agriculture and Food Science* 35(2):319-331.

Azmi, M., Juraimi, A.S., and Najib, M.M.Y. 2007. Critical period for weedy rice control in direct-seeded rice. *Journal of Tropical Agriculture Food Science* 35:319-332.

Azmi, M. and Othman, O. 1987. Competitive ability of selected rice varieties under direct seeding. (Saingan rumpai dengan beberapa variety/baka padi yang ditanam secara tabor terus. *Teknologi Padi* (Jilid 3).

Balasubramanian, V., Morales, A.C., Cruz, R.T., and Abdulrahman. 1999. On farm adaptation of knowledge-intensive nitrogen management technologies for rice systems. *Nutri. Cycl. Agroecosyst.* 53(1): 59-69.

Balasubramanian, V. and Hill, J.E. 2002. *Direct seeding of rice in Asia: Emerging issues and strategic research needs for the 21st century. pp. 15-39.* In Direct Seeding: Research strategies and opportunities. Pandey *et al.* Eds. IRRI, Los Banos, Philippines.

Baloch, A.W., Soomro, A.M., Javed, M.A., and Ahmed, M. Optimum Plant Density for High Yield in Rice (*Oryza sativa* L.). *Asian Journal of Plant Sciences* 1(1): 25-27.

Baki, B.B. and Azmi, M. 1994. *Integrated management of paddy and aquatics weeds in Malaysia: current status and prospects for improvement.* In Shibayama, H., Kiritani, K., Bay-Peterson,J. eds. Integrated Management of Paddy and Aquatic Weeds and Prospects for Biological Control. Taipei, Taiwan: Food and Fertilizer Technology Center for the Asian and Pacific Region, FFTC Book Series No.45.p46-77.

Baltazar, A.M., Martin, E.C., Casimero, E.C., Bariuan, F.V., Obien, S.R. and De Datta, S.K. 1998. *Major weeds in rain-fed rice-onion cropping systems in the Asian site in the Philippines*. IPM CRSP Working Paper 98-1. p24.

Barker, R., Dawe, D., Tuong, T.P., Bhuiyan, S.I., and Guerra, L.C. 1998. *The outlook for water resources in the year 2020: Challenges for research on water management in rice production*. In: Proceedings of 19th session of the International Rice Commission: Assessment and orientation towards the 21st century, 7-9 September 1998, Cairo, Egypt, FAO, pp. 96-109.

Barr, C.J., Bunce, R.G.H., Clarke, R.T., Fuller, R.M., Furse, M.T., Gillespie, M.K., Groom, G.B., Hallam, C.J. and Horning, M. 1993. *Countryside survey : main report*. Department of Environment, Eastcote, UK.

Bastiaans, L., Zhao, D.L., Den Hollander, N.G., Baumann, D.T., Kruidhof, H.M. and Kropff, M.J. 2007. *Exploiting diversity to manage weeds in agro-ecosystems*. In Spiertz, J.H.J., Struik, P.C., van Laar, H.H. (eds). Scale and Complexity in Plant Systems Research: Gene-Plant-Crop Relations, 267-284.

Becker, M. and Johnson, D.E. 1999. The role of legume fallows in intensified upland rice-based systems in West Africa. Nutrition Cycle Agroecosystems 53: 71-81

Bell M., Balasubramaniam, V. and Rickman, J. 2003. *Rice Fact Sheets*. International Rice Research Institute, Los Banos, Philippines.

Belder, P., Bouman, B.A.M., Cabangon, R., Quilang, E.J.P., Spiertz, J.H.J. and Tuong, T.P. 2004. Effect of water-saving irrigation on rice yield and water use in typical lowland conditions in Asia. *Agriculture Water Management* 65: 193-210.

Berkowitz, A.R. 1988. *Competition for resources in weed-crop mixtures*. In Altieri, M.A. and Liebman, M. (eds). Weed Management in Agroecosystems:Ecological Approaches. Boca Raton, FL:CRC Press. P89-120.

Bhan, V.M. 1983. *Effects of hydrology, soil moisture regime and fertilizer management on weed populations and their control in rice*. In Proceedings of the Conference on Weed Control in Rice. pp 47-56. IRRI-IWSS. Los Banos, Philippines.

Bhagat, R.M., Bhuiyan, S.I., Moody, K., and Estorninos, L.E. 1999. Effect of water, tillage and herbicide on ecology of weed communities in intensive wet-seeded rice system. *Crop Protection* 18: 293-303.

Bhagat, R.M., Bhuiyan, S.I., and Moody, K. 1996. Water, tillage and weed interactions in lowland tropical rice: a review. *Agricultural Water Management* 31:165-184

Bhatt, M.D and Tewari, A. 2006. Losses in growth and yield attributes due to weed composition in transplanted paddy in Terai Region. *Scientific World* 4: 99-101.

Blackshaw, R.E., Larney, F.O., Lindwall, C.W. and Kozub, G.C. 1994. Crop rotation and tillage effects on weed populations on the semi-arid Canadian priaries. *Weed Technology* 8:231-237.

Bouman, B.A.M. 2001. *Water-Efficient Management Strategies in Rice Production*, International Rice Research Notes, vol 16.2 IRRI, Los Banos, Philippines.

Bouman, B.A.M. 2003. *Examining the water-shortage problem in rice systems: water saving irrigation technologies*. In: Mew T.W. et al (eds), Proceedings of the International Rice Research Conference, Beijing, China, 16-19 September 2002.

Bouman, B.A.M., Lampayan, R.M. and Tuong, T.P. 2007. *Water management in irrigate rice*: Coping with water scarcity. International Rice Research Institute, Los Banos Philippines. 54p

Bouman, B.A.M., Wang, H., Yang, X., Zhao, J. and Wang, C. 2002. *Aerobic rice (Han Dao): A new way of growing rice in water-short areas.* In Proceedings of the 12th International Soil Conservation Organization Conference, 26-31 May 2002, Beijing, China. Tsinghua University Press, pp. 175-181.

Bouman, B.A.M., Peng, S., Castaneda, A.R. and Visperas, R.M. 2005. Yield and water use of irrigated tropical aerobic rice systems. *Agriculture Water Management* 74: 87-105.

Bouman, B.A.M., Humpreys, E., Tuong, T.P. and Barker, R. 2006. Rice and water. *Advanced Agronomy* 92: 187-237.

Bouman, B.A.M. and Tuong, T.P. 2000. Field water management to save water and increase its productivity in irrigated lowland rice. *Agricultural Water Management* 1615:1-20.

Buhler, D.D. 2002. Challenges and opportunities for integrated weed management. *Weed Science* 50(3): 273-280

Callaway, M. 1992. A compendium of crop varietal tolerance to weeds. *Am. J. Alternative Agriculture* 7:169-180.

Casimero,M.C. and Juliano, L.M. 2004. *Agroecological approaches to managing weeds in wet direct seeded rice*. Proceedings of the 14th Australian Weeds Conference, eds. Sindel, B.S. and Johnson, S.B. pp121-124 (Weed Society of New South Wales, Sydney).

Castaneda, A.R., Bouman, B.A.M., Peng, S. and Visperas, R.M. 2004. *Mitigating water scarcity through an aerobic system of rice production*. Proceedings of the 4th International Crop Science Congress, Australia.

Caton, B.P., Cope, A.E. and Mortimer, M. 2003. Growth traits of diverse rice cultivars unde severe competition: implications for screening for competitiveness. *Field Crops Research* 83: 157-172.

Champion, G.T., Froud-Williams, R.J. and Holland, J.M. 1998. Interactions between wheat (*Triticum aestivum* L.) cultivar, row spacing and density and the effect on weed suppression and crop yield. *Annual Applied Biology* 133:443-453

Chauhan, B.C. and Johnson, D.E. 2010. Responses of rice flatsedge (*Cyperus iria*) and barnyardgrass (*Echinochloa crus-galli*) to rice interference. *Weed Science* 58: 204-208.

Chauhan, B.G., Singh, R.G. and Mahajan, G. 2012. Ecology and weed management of weeds under conservation agriculture: A review. *Crop Protection* 38: 57-65

Chauhan, B.S., and Johnson, D.E. 2011. Row spacing and weed control timing affect yield loss in aerobic rice. *Field Crops Research*. 117:177-182.

Champion, G.T., Froud-Williams, R.J. and Holland, J.M. 1998. Interactions between wheat (*Triticum aestivum* L.) cultivar, row spacing, and density and the effect on weed suppression and crop yield. *Annals Applied Biology* 133:443-453.

Conway, G.R. and Pretty, J.N. 1991. *Unwelcome harvest: agriculture and pollution*. London: Earthscan Publication Ltd.55p

Dawe, D., Frolking, S. and Changseng, L. 2004. Trends in rice-wheat are in China. *Field Crops Research* 87: 89-95.

De Datta, S.K., and Llagas, M.A. 1984. *Weed problems and weed control in upland rice in tropical Asia*. In: An overview of upland research IRRI, Los Banos, Laguna, Phillipines. Pp:321-342.

De Vida, F.B.P., Laca, E.A., Mackill, D.J., Grisel, M. and Fischer, A.J. 2006. Relating rice traits to weed competitiveness and yield: a path analysis. *Weed Science* 54: 1122-1131.

Department of Agriculture. 2010.Seksyen Industri Padi dan Beras (IPB). Accessed on 22 June 2011.

Dewar, A.M., May, M.J., Woiwood, I.P., Haylock, L.A., Champion, G.T., Barner, B.H., Sands R.J.N., Qi, A. and Pidgeon, J.D. 2003. *A novel approach to the use of genetically modified herbicide tolerant crops*. Proceedings of the Royal Society of London Series B-Biological Science 270: 335-340.

Deihimfard, R., Hejazi, A., Zand, E., Baghestani, M.A.,Akbari, Gh. Ab. And Soufizadeh, S. 2006. Comparing the Competitive Ability of Old and New Wheat Cultivars against Rocket (*Eruca sativa*). Iran. *Iranian Journal of Weed Science* 2: 53-68

Dilday, R.H., Lin, J. and Yan, W. 1994. Identification of allelopathy in the USDA-ARS rice germplasm collection. *Australian Journal of Experimental Agriculture* 34: 907-910.

Dingkuhn, M., Johnson, D. E., Sow, A. and Audebert, A.Y. 1999. Relationship between upland rice canopy characteristics and weed competitiveness. *Field Crops Research* 61:79-95.

Dofing. S.M. and Karlsson, M.G. 1993. Growth and development of uniculm and conventional –tillering barley lines. *Agronomy Journal* 85, 58-61

Doorenbos, J. and Pruit, W.O. 1984. *Guidelines for predicting crop water requirements*. FAO Irrigation and Drainage paper 24, Food and Agriculture Organization, Rome, Italy, p44.

Drost, D.C. and Moody, K. 1982. Effect of butachlor on *Echinochloa glabrescens* in wet-seeded rice (*Oryza sativa* L.) *Philippine Journal Weed Science* 9, 57-74.

Ekeleme, F., Kamara, A.Y., Oikeh, S.O., Chikoye, D. and Omoigui, L.O. 2007. *Effect of weed competition on upland rice production in north-eastern Nigeria*. African Crop Science Conference Proceedings. Vol 8: 61-65.

Estorninos, L.E. Jr. and Moody, K. 1976. *The effect of plant density and weed control in transplanted rice*. Paper presented at the 7th Annual Conference Pest Control Council Philippine Cagayan de Oro City, 5-7 May, 1976. 13p

Estorninos, L.E.J., Gealy, D.R., Talbert, R.E. and Gbur. E.E. 2005. Rice and red rice interference. I. Response of red rice (*Oryza sativa*) to sowing rates of tropical japonica and indica rice cultivars. *Weed Science*. 53:676-682.

Farooq, M., Kobayashi, N., Wahid, A., Ito, O. and Basra, S.M.A. 2009. Strategies for producing more rice with less water. *Advances in Agronomy* 101: 352- 388.

FAO (Food and Agriculture Organization). 1998. *Crop Evaporation: guidelines for computing crop water requirements*. Irrigation and Drainage Paper 56. FAO, Rome. 300p

FAO (Food and Agriculture Organization of the United Nations). 2004. Rice and us. http://www.fao.org/rice2004/en/aboutrice.htm. Accessed on 7th February 2011.

FAO (Food and Agriculture Organization of the United Nations).1998. In Report of the Fifth External Programme and management review of International Rice research Institute. Food Agriculture Organization of the United Nations. 10pp

FAO, 2007. FAO statistical databases. http:/faostat.fao.org/.Accessed on 7th February 2011.

Fageria, N. K., Baligar, V. C. and Jones, C. A. 1997. *Growth and Mineral Nutrition of Field Crops*. New York : Marcel Dekker

Fernando, B.P. Laca, E.A., Mackill, D.J., Fernandez, G.M. and Fischer, A, J. 2006. Relating rice traits to weed competitiveness and yield: a path analysis. *Weed Science* 54:1122-1131.

Filizadeh, H., Rezazadeh,A. and Younessi, Z. 2007. Effects of crop rotation and tillage depth on weed competition and yield of rice in the paddy fields of the Northern Iran. *Journal Agriculture Science Technology*. 9:99-105

Fischer, A.J., Chatel, M., Ramierz, H., Lozano, J. and Guimaraes, E. 1995. Components of early competition between upland rice (*Oryza sativa*) and *Brachiaria brizantha*(Hochst.ex A. Rich) . *International Journal of Pest Management* 41:100-103

Fischer, A.J., Ramierz, H.V., Gibson, K.D. and Pinheiro, B.D.S. 2001. Competitiveness of semi dwarf rice cultivars against palisadegrass (*Brachiaria brizantha*) and signalgrass (*Brachiaria decumeans*) . *Agronomy Journal* 93: 967-973.

Fofana, B. and Rauber, R. 2000. Weed suppression ability of rice under low-input conditions in West Africa. *Weed Research* 40: 271-280.

Fujisaka, S., Moody, K. and Ingram, K., 1993. A descriptive study on farming practices for dry seeded rainfed lowland rice in India, Indonesia and Myanmar. *Agriculture Ecosystem Environment* 45: 115-128

Garrity, D.P., Movillon, M. and Moody, K. 1992. Differential weed suppression ability in upland rice cultivars. *Agronomy Journal* 84:586-591.

Gaudet, C.L. and Keddy, P.A. 1988. A comparative approach to predicting competitive ability of plant traits. *Nature* 334: 242-243.

Ghadiri, H. and Bayat, M.L. 2004. Effect of Row and Plant Spacings on Weed Competition with Pinto Beans (*Phaseolus vulgaris* L.). *J. Agric. Sci. Technol*. 6:1-9.

Gholam, R. 2007. Growth parameters enhancing the competitive ability of corn (*Zea mays* L.) against weeds. *Weed Biology and Management* 7: 232-236.

Gibson, K.D., Fischer, A.J., Foin, T.C. and Hill, J.E. 2003. Crop traits related to weed suppression in water seeded rice (*Oryza sativa* L.). *Weed Science* 51, 87-93

Gleick, P. H. 1993. *Water in Crisis: A guide to the World's Fresh Water Resources*. New York: Oxford University Press.

Grace, J.B. 1990. *On the relationship between plant traits and competitive ability*. In: Perspective on Plant Competition (ed. by Grace J.B. and Tilman D.). Academic Press, San Diego, CA, 51–65.

Guerra, L.C., Bhuiyan, S.I., Tuong, T.P., and Barker, R. 1998. *Producing more rice with less water from irrigated systems*. SWIM Paper No 5. International Water Management Institute. P.O. Box 2075, Colombo, Sri Lanka.

Haefele, S.M., Johnson, D.E., Bodj, D.M., Wopereis, M.C.S. and Miezan, K.M. 2004. Field screening of diverse rice genotypes for weed competitiveness in irrigated lowland ecosystems. *Field Crop Research* 88: 39-56

Harker, K.N., O'Donovan, J.T., Irvine, R.B., Turkington, T.K. and Clayton. G.W. 2009. Integrating cropping systems with cultural techniques augments wild oat (*Avena fatua*) management in barley. *Weed Science* 57:326-337.

Hasanuzzaman, M., Rahman, M.L., Roy, T.S., Ahmed, J.U. and Zobaer, A.S.M. 2009. Plant Characters, Yield Components and yield of late transplanted Aman rice as

affected by plant spacing and number of seedling per hill. *Advances in Biological Research* 3 (5-6):201-2

Harper, J.L. 1977. *Population Biology of Plants*. Academic Press, London, 892pp.

Hill, J.E., Smith Jr, R.J. and Bayer, D.E. 1994. *Rice weed control: current technology and emerging issues in the United States*. In 'Proceedings of the Temperate Rice Conference'. New South Wales, Australia: NSW Agriculture. pages 377-391

Ho, N.K. and Zuki, M.D. 1988. *Weed population changes from transplanted to direct seeded rice in the Muda area*. Proceedings of the National Seminar & Workshop on Rice Field Weed Management (edited by Lam, Y.M. Cheong, A.W. and Azmi, M) Penang, 7-9 June 1989, pp 55-68.

Hooda, I.S. 2002. *Weed management in organic rice*. 1st RDA/ARNOA International Conference 'Development of Basic Standard for Organic Rica Cultivation'. 12-15 November. RDA and Dankook University of Korea.

Huel, D.G. and Hucl. P. 1996. Genotypic variation for competitive ability in spring wheat. *Plant Breeding* 115:325-329.

Huke, R.E and Huke, E.H. 1997. *Rice Area by Type of Culture: South, Southeast and East Asia*. Los Banos, Philippines: International Rice Research Institute, 59p.

Hussain, F. Bronson, K.F., Sing, Y., Sing, B. and Peng, S. 2000. Use of chlorophyll Meter Sufficiency Indices for Nitrogen Management of Irrigated Rice in Asia. *Agronomy Journal* 92: 875-879.

Islam, M. Sh., Bhuiya, M.S.U., Rahman, S. and Hussain, M.M. 2009. Evaluation of SPAD and LCC based on nitrogen management in rice (Oryza sativa L.) *Bangladesh Journal Agricultural Research* 34(4): 661-62

IRRI (International Rice Research Institute), 1997. *Rice Almanac*. 2nd edition. IRRI, Los Banos, Philippines. 181p.

IRRI, 2008: Online documents at http://www.irri.org/science/cyinfo/index.asp. Assessed on 26 February 2012

International Rice Research Institute.2003. *Report of the Director General 2002-2003*. Volume 13. 113 pp.

Janiya, J.D. and Moody, K. 1989. Weed populations in transplanted wet-seeded rice as affected by weed control method. *Tropical Pest Management* 35(1): 8-11.

Janiya, J.D. and Moody, K. 1991. Effect of water deficit on rice-weed competition under glass house conditions. *Journal of Plant Protection in the Tropics*. 8(1), 25-35.

Jannink, J.L., Orf, J.H., Jordan, N.R. and Shaw, R.G. 2000. Index selection for weed suppressive ability in soybean. *Crop Science* 40:1087-1094.

Jaya Suria, A.S.M., Juraimi, A.S., Rahman, M.M., Man, A.B. and Selamat, A. 2011. Efficacy and economics of different herbicides in aerobic rice system. *African Journal of Biotechnology* 10 (41): 8007-8022.

Jennings, P.R. and Aquino, R.C. 1968. Studies on competition in rice: III. The mechanism of competition among phenotypes. *Evolution* 22:529-542

Jennings, P.R. and De Jesus, J.Jr. 1968. Studies on competition in rice: I. Competition in mixtures of varieties. *Evolution* 22:119-124

Jennings, P.R. and Herrera, R.M. 1968. Studies on competition in rice: II. Competition in segregating populations. *Evolution* 22: 332-336

Johnson, D.E. 1996. *Weed management in small holder rice production in the tropics*. Natural Resources Institute. University of Greenwich Ghatham, Kent, UK., pp:11

Johnson, D.E., and Mortimer, A.M. 2008. *Issues for weed management in direct-seeded rice and the development of decisision-support frameworks*. In Singh, Y., Singh, V.P., Chauhan, B., Orr, A., Mortimer, A.M., Johnson, D.E. and Hardy, B. (eds). Direct Seeding of Rice and weed management in the Irrigated Rice-Wheat Cropping System of the Indo-Gangetic Plains, Los Banos, Philippines: International Rice Research Instite and Pantnagar, India: Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology. Pages 223-228

Jones, M.P. Johnson, D.E., Fofana, B. and Koupuer, T. 1994. *Determining traits that enhance weed competitiveness in upland rice*. In: 1994 WARDA Annual Report, 48-50 West Africa Rice Development Association, Bouake, Cote d'Ivore.

Jordan, N. 1993. Prospects for weed control through crop interference. *Ecology Application* 3: 84-91.

Karim, R.S.M., Azmi, M. and Ismail, S. 2004. Weed problems and their management in rice fields of Malaysia: An Overview. *Weed Biology and Management* 4:177-186.

Kato, Y., Kamoshita, A. and Yamagishi, J. 2007. Evaluating the resistance of six rice cultivars to drought: restriction of deep rooting and the use of raised beds. *Plant Soil* 300: 149-161.

Kim, S.C. and Moody, K. 1983. Effect of mixture of two rice cultivars of the competitive ability of rice against weeds and rice grain yield. *Philippines Journal of Weed Science* 7: 17-25

Kim, S.C. and Moody, K. 1980. Effect of plant spacing on the competitive ability of rice in association with various weed communities at different nitrogen levels. *Journal of Korean Society Crop Science* 25:17-27.

Khush, G.A. 1997. Origin, dispersal, cultivation and variation of rice. *Plant Molecular Biology* 35:25-34.

Konesky, D.W., Siddiqi, M.Y., Glass, A.D.M. and Hsiao, A.I. 1989. Wild oat and barley interactions: Varietal differences in competitiveness in relation to phosphorus supply. *Journal of Botany* 67:3366-3371.

Labrada, R. 1996. *Weed management in rice*. In Auld, B.A. and Kim, K.U. (eds). FAO Plant Production and Protection Paper, FAO, Rome. No. 139, p. 259-272

Labrada, R. 2003. *The need for improved weed management in rice*. In: Sustainable Rice Production for Food Security.Proceedings of the 20th Session of the International Rice Commision Bangkok, Thailand. 23-26 July.

Lampkin, N. 2003. *Organic farming*. In: Soffe, R.J. eds. The agricultural notebook. Oxford: Blackwell Science, p288-303.

Lemerle, D., Verbeck, B., Cousens, R.D. and Coombes, N.E. 1996. The potential for selecting wheat varieties strongly competitive against weeds. *Weed Research* 36: 505-513.

Lemerle D., Verbeek, B. and Orchard, B. 2001. Ranking the ability of wheat varieties to compete with *Lolium rigidum*. *Weed Research* 41: 197-209.

Ludi, E. 2009. *Climate change, water and food security*. Background Note March 2009. Overseas Development Institute.

Madonni, G.A., Cirilo, A.G. and Otegui, M.E. 2003. Row Width and Maize Grain Yiels. *Agronomy Journal* 98: 1532-1543.

Martin, G.J., Padmanathan, P.K. and Subramaniam, F. 2007. Identification on Suitable Rice Variety Adaptability to Aerobic Irrigation. Journal of Agricultural and Biological Science, 2:1-3

Maske, N.S., Borkar, S.I. and Rajgire, H.J. 1997. Effect of nitrogen levels on growth, yield and grain quality of rice. *Journal of Soils and Crops*. 7:83-89.

Mcdonald, G.K. 2003. Competitiveness against grass weeds in field pea genotypes. European Weed Research Society. *Weed Research*, 43: 48-58.

Maclean, J.L., Dawe, D.C., Hardy, B. and Hettel, G.P. 2002. *Rice Almanac*. Los Baños (Philippines): International Rice Research Institute, Bouaké (Cote d'lvoire):West Africa Rice Development Association, Cali (Colombia): International Center for Tropical Agriculture, Rome (Italy): Food and Agriculture Organization, 253 p.

Mercado, B.L., De Datta, S.K., Migo, T.R. and Baltazar, A.M. 1990. Growth behavior and leaf morphology of Philippine strains of Sphenochlea zeylanica showing differential response to 2,4-D. *Weed Research* 30: 245-250.

Mishra, A. and Salokhe, V.M. 2010. The effects of plating pattern and water regime on root morphology, physiology and grain yield of rice. *Journal of Agronomy and Crop Science* 196 : 368-378.

Monaco, T.J., Welter, S.C. and Ashton, F.M. 2002. *Weed Science: Principles and Practices* (4th ed.). John Wiley & Sons. Inc., New York

Moody, K. 1983. *The status of weed control in rice in Asia*. FAO Plant Protect. Bull. 30 (3/4): pp 119 – 123

Munene, J.T., Kinyamario, J.I., Holst, N. and Mworia, J.K. 2008. Competition between cultivated rice (*Oryza sativa*) and wild rice (*Oryza punctata*) in Kenya. *African Journal of Agricultural Research*, 3(9): 605-611

Navares, D.C. and Moody, K. 1991. Effects of weed control and tillage in a rice-mungbean crop rotation. *Journal of Plant Protection in the Tropics* 8(1):13-23

Ni, H., Moody, K., Robles, R.P., Paller, E.C. and Lales, J.S. 2000. *Oryza sativa* plant traits conferring competitive ability against weeds. *Weed Science* 48: 200-204

Noda, K., Ozawa, K. and Ibaraki, K. 1968. Studies on the damage to rice plants due to weed competition (effect of barnyard competition on growth, yield and some eco-physiological aspects of rice plants). *Kyushu Agriculture Exp. Sta. Bulletin*. 13:345-367

Noda, K. 1977. *Integrated weed control in rice*. In integrated control of weeds. Frayer, J.D. and Matsunaka, S. Eds. Tokyo (Japan): University of Tokyo Press. pp. 17-46.

O'Donovan, J.T., Harker, K.N., Clayton, G.W. and Hall, L.M. 2000. Wild oat (*Avena fatua*) interference in barley (*Hordeum vulgare*) is influenced by barley variety and seeding rate. *Weed Technology* 14 : 624-629.

Oerke, E. C. and Dehne, H.W. 2004. Safeguarding production- Losses in major crops and the role of crop protection. *Crop Production* 23(4):275-285.

Ooi, P.A.C. and Casimero, M.C. 2004. *Facilitating weed management skills by resource poor farmers*. Proceedings Pest Management Council of the Philippines Conference. Pp 35-50.

Omina El-Shayieb, M.A. 2003. *Agronomic study on rice crop*. M.Sc. Thesis Agronomy Department Faculty of Agriculture, Egypt.

Page, E.R., Tollenaar, M., Lee, E.A., Lukens, L. and Swanton, C.J. 2010. Shade avoidance: an integral component of crop-weed competition. *Weed Research* 50:281-288.

Pande, H.K. 1994. *Improved upland rice farming systems*. Food and agriculture organization of the United Nations, Rome, pp. 31-108.

Pacanoski, Z. and Glatkova, G. 2009. The use of herbicides for weed control in direct wet – seeded rice (*Oryza sativa* L.) in rice production regions in the Republic of Macedonia. *Plant Protection Science* 45: 113-118.

Park., S.E., Benjamin, L.R. and Watkinson, A.R. 2003. The theory and application of plant competition models: an agronomic perspective. *Annals of Botany* 92:741-748

Peng, S., Bouman, B.A.M., Visperas, R.M., Castaneda, A., Nie, L. and Park, H.K. 2006. Comparison between aerobic rice and flooded rice: agronomic performance in a long term (8 seasons) experiment. *Field Crops Research* 96: 252-259.

Peng, S., Khush, G.S. and Cassman, K.G. 1994. *Evaluation of a new plant ideotype for increased yield potential*. P.5-20. In Cassman, K.G. (ed.) Breaking the yield barrier: Proceedings of a workshop on rice yield potential in favorable environments, Los Banos, Philippines. 29 Nov-4 Dec. 1993. International Rice Research Institute, Los Banos, Philippines.

Peng, S., Garcia, F.V., Laza, C., Sanico, A.L., Visperas, R.M. and Cassman, K.G. 1996. Increased N-use efficiency using a chlorophyll meter on high-yielding irrigated rice. *Field Crops Research* 47: 243-252.

Perera, K.K., Ayres, P.G. and Guanasena, H.P.M. 1992. Root growth and the relative importance of root and shoot competition in interaction between rice (*Oryza sativa*) and *Echinochloa crus-galli. Weed Research* 32: 67-76

Pester, T.A., Burnside, O.C. and Orf, J.H. 1999. Increasing crop competitiveness to weeds through crop breeding. *Journal of Crop Production* 2:31-58.

Powlers, S.B and Shaner, D.L. 2001. *Herbicide resistance and world grains*. London : CRC Press.

Primot, S., Valentin-Morrison, M. and Makowski, D. 2006. Predicting the risk of weed infestation in winter oilseed rape crops. *Weed Research* 46: 22-33.

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

Reddy, T.Y. and Redd, G.H. 1997. *Principle of Agronomy*. Kalyani Publication, New Delhi India. 515 p.

Renault, R. 2004. *International year of rice: Rice is Life*. Food and Agriculture Organization of the United Nations.

Renault and Facon . 2004. "*Beyond drops for crops: a system approach for assessing the values of water in rice-based systems"* . Proceedings of the FAO Rice Conference **"***Rice is Life"* Available at http://www.fao.org/docrep/008/y5682e/y5682e09.htm. Assessed on 20 November 2012.

Riches, C.R., Mbwaga, A.M., Mbapila, J. and Ahmed, G.J.U. 2005. Improved weed management delivers increased productivity and farm incomes from rice in Bangladesh and Tanzania. *Aspects of Applied Biology* 75:127–138

Rijsberman, F.R. 2006. Water Scarcity: Fact of fiction? *Agriculture Water Manage* 80: 5-22

Roa, V.S. 2000. *Principles of weed science*. New Delhi, India: Oxford and IBH publishing Co. Pvt. Ltd. pp. 36-56.

Robinson, R.A. and Sutherland, W.J. 2002. Post war changes in arable farming biodiversity in Great Britain. *Journal of Applied Ecology* 39: 157-176.

Rodernburg, J., Saio, K., Kakai, K.G., Toure, A., Mariko, M. and Kiepe, P. 2009. Weed competitiveness of the lowland rice varieties of NERICA in the Southern Guinea Savanna. *Field Crops Researc*h 114:411-418.

Rodernburg, J. and Meinke, H. 2010. *Adapting weed management in rice to changing climate*. In: Innovation and Partnership to Realize Africa's Rice Potential. Second Africa Rice Congress, Bamako, Mali, 22-26 March.

Roush, M.L. and Radosevich, S.R. 1985. Relationships between weed growth and competitiveness of four annual weeds. *Journal of Applied Ecology* 22:895-905.

Russo, S. 1996. *Preliminary studies on rice varieties adaptability to aerobic irrigation*. CIHEAM-Options Mediterraneennes. p35-39.

SAS (Statistical Analysis System). 2003. The SAS system for Windows, Version 9.1, SAS Inst. Inc., Cary, NC, USA.

Saito, K., Azoma, K. and Rodenburg, J. 2010a. Plant characteristics associated with weed competitiveness of rice under upland and lowland conditions in West Africa. *Field Crops Research* 116: 308-317.

Saito, K.,Azoma, K. and Sie, M. 2010b. Grain yield performance of selected lowland NERICA and modern Asian rice genotype under non-fertilized and fertilized conditions in rice lowlands of West Africa. *Crop Science* 50: 281-291.

Sariam, O. 2010. *Fertilizer Management for Aerobic Rice Cultivation*. In: The 3rd International Rice Congress held in Hanoi, Vietnam, 8-12 November 2010.

Salem, A.K.M. 2006. Effect of Nitrogen levels, plant spacing and time of farmyard manure application on the productivity of rice. *Journal of Applied Sciences Research* 2(11): 980-987.

Sharma ,H.C., Singh, H.B. and Friesen, G.H. 1979. Competition from weeds and their control in direct-seeded rice. *Weed Research* 17: 103-108

Sen, D.N. 2000. *Weeds in rainfed cropping in Indian desert*. In: Environment and Agriculture: At the cross road of New Millennium Vol I (eds). Jha, P.K., Karmacharya, S.B., Baral, S.R. and Lacuol, P. Ecological Society (ECOS), Kathmandu, Nepal, pp 223-228.

Sheley, R., Manoukian, M. and Marks, G. 2002. *Noxious Weed Invasion Extension Bulletin*. Montana State University

Sinar Harian, 2 Jun 2013. "Stok beras membimbangkan'. http://www.sinarharian.com.my/edisi/perak/stok-beras- membimbangkan-1.166681. Retrieved on 16th October 2013.

Singh, A.K. and Chinnusamy, V. 2006. Aerobic Rice: Prospects for Enhancing Water Productivity. *Indian Farming* October 2006.

Suzuki, T., Shiraiwa, T. and Horie, T. 2002. Competitiveness of four rice cultivars against barnyard grass (*Echinochloa oryzicola* vasing) with reference to root and shoot competition. *Plant Prod. Sci*. 5:77-82.

Swain, D. K. and Sandip, S.J. 2010. Development of SPAD Values of Medium and

Long-duration Rice Variety for Site-specific Nitrogen Management. *Journal of Agronomy* 9 (2): 38-44

Tabbal, D.F., Bouman, B.A.M. Bhuiyan, S.I., Sibayan, E.B. and Sattar, M.A. 2002. On-farm strategies for reducing water input in irrigated rice: case studies in the Philippines. *Agricultural Water Management* 56 : 93-112.

Tao, H., Brueck, H., Dittert, K., Kreye, C., Lin, S., Sattelmacher, B. 2006. Growth and yield formation of rice (Oryza sativa L.) in the water saving ground cover rice production system (GCRPS). *Field Crops Research* 95: 1-12.

Tuong, T.P. and Bouman, B.A.M. 2003. *Rice production in water –scarce environments*. In Proceedings of the Water Productivity Workshop. 12-14 November 2001, Colombo, Sri Lanka. International Water Management Institute. Colombo, Sri Lanka.

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 systems in Asia. *Plant Production Science* 8: 231-241.

Turner, F.T. and Jund, M.F. 1994. Assessing the nitrogen requirement of rice crops with a chlorophyll meter. *Australia Journal Experimental Agriculture* 34: 1001-1005

Valverde, B.E. 1996. *Management of herbicide resistant weeds in Latin America; The caase of propanil-resistant Echinochloa colona in rice*.. In International Weed Control Congress., 2nd, Copenhagen. 25-28 June 1996. Department of weed control and pesticide ecology, Flakkebjerg, Denmark. p415-420.

Valverde, B.E., Riches, C.R. and Caseley, J.C. 2000. Prevention and management of herbicide resistant weeds in rice: Experiences from Central America with *Echinochloa colona*: Camara de Insumos Agrolecuarious, San Jose, Costa Rica.

Vial, L. 2007. *Growing rice with less water*. IREC Farmers' Newsletter, No. 176.

Wang, H.Q., Bouman, B.A.M., Zhao, D.L., Wang, C. and Moya, P. F. 2002. *Aerobic rice in northern China: Opportunities and challenges.* In Water-Wise Rice Production. Bouman, B. A.M., Hengsdijk, H., Hardy, B., Bindraban, P.S., Tuong, T.P. and Ladha, J.K. Eds. Proceedings of a Thematic Workshop on Water-Wise Rice Production, 8–11 April 2002 at IRRI Headquarters in Los Banos, Philippines.

WARDA. *Annual report for 1995*. 1996. West Africa Rice Development Association, Bouake, Cote d'Ivoire.

Wassmann, R., Lantin, R.S. and Neue, H-U. eds. 2000. *Methane emissions from major*

rice ecosystems in Asia. Developments in plant and soil sciences. Dordrecht (the Netherlands) : Kluwer Academic Publishers. Vol 91:395 p.

Whiting, A.J., Richards, M.C. and Brown, H. 1990. Crop competitiveness as an aid to weed control in cereals. *Monograph-British Crop Protection Council*. p. 197-200.

Weiner, J., Griepentrog, H.W. and Kristensen, L. 2001. Suppression of weeds by spring wheat *Triticum aestivum* increases with crop density and spatial uniformity. *Journal of Applied Ecology* 38: 784-790.

William M.M II., Boydston, R.A. and Davix, S. 2007. Wild Proso Millet (*Panicum miliaceaum*), Suppressive Ability among Three Sweet Corn Hybrids. *Weed Science* 55: 245-251.

Wood, C. W., Reeves, D. W. and Himelrick, D. G. 1993. Relationships between chlorophyll meter readings and leaf chlorophyll concentration, N status and crop yield: A review. *Proc. Agron. Soc. N. Z.* 23: pp 1-9.

Yoshida, S. 1981. *Fundamentals of Rice Crop Science*. International Rice Research Institute, Los Banos, Laguna, Philippines.

Zafar, M., Asif, T., Zahid, A.C. and Ashraf, M. 2010. Weed-crop competition effects on growth and yield of sufarcane planted using two methods. *Pakistan Journal Botany* 42(2):815-823.

Zahran, H.A.A. 2000. *Response of some rice cultivars to different spaces among hills and rows under saline soil conditions*. MSc. Thesis, Faculty Agriculture, MAnsoura University, Egypt.

Zhao, D.L., Atlin, G.N., Bastiaans, L. and Spiertz. J.H.J. 2006. Developing selection protocols for weed competitiveness in aerobic rice. *Field Crops Research* 99:272-285.

Zimdahl, R.L. 1980. *Weed-crop competition- a review*. International Plant Protection Center, Oregon State University, Corvallus, OR. pp. 83-126.

Zimdahl, R.L. 2004.*Weed crop competition*: A review. Blackwell Publishing Ltd.

Zoschke, A. 1991. *Yield losses in tropical rice as influenced by the composition of weed flora and the timing of its elimination*. Pest Management in Rice (Grayson, B.T., Green, M.B., Copping, L.G. ed). London, UK. Elsevier Science Publication Ltd. Pp 300-313.