UNIVERSITI PUTRA MALAYSIA

STRATEGIES FOR WEED SUPPRESSION IN AEROBIC RICE CULTIVATION

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By

MD. PARVEZ ANWAR

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

April 2012

DEDICATION

To my beloved motherland BANGLADESH, a place of love and peace.

To my loving parents; they know why.

To my wife Rita, who made me laugh, brought my supper and made my life special.

Also to my little prince Mugdho, for giving me happiness and joy.

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

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April 2012

Chairman: Associate Professor Abdul Shukor Juraimi, PhD

Institute: Institute of Tropical Agriculture

Aerobic rice, a promising water-wise rice production system, is highly vulnerable to weed invasion which demands an effective weed management strategy. This study was, therefore, initiated aimed at developing a more comprehensive integrated weed management system for aerobic rice. Thirteen rice varieties were evaluated for their weed suppressive ability and productivity under aerobic soil conditions. Rice varieties differed widely in their weed suppressive ability and yield. AERON 1 exhibited very strong weed suppressive ability and highest yield potential closely followed by AERON 4. Two seeding methods and three seeding rates were tested to identify suitable method and seeding rate in terms of weed suppression and yield of AERON 1. Weed density and dry weight decreased gradually with increased seeding rate but were independent of seeding methods. Row seeding produced higher grain yield compared to broadcast seeding. Increasing seeding rate up to 300 seeds/m^2 was found worthwhile to reduce weed pressure without sacrificing rice yield. An attempt was made to explore the possibility of adopting

seed priming technique as a tool for weed management. Seed priming considerably improved germination attributes, weed suppressive ability and yield of AERON 1. Zappa® priming was the best in terms of weed suppression and yield. In herbicide screening trial, eight herbicide formulations were applied in different combinations. Most of the herbicides provided excellent weed control. In terms of weed control efficacy and cost effectiveness, Cyhalofop-butyl + Bensulfuron followed by (fb) Bentazon/MCPA performed the best. Among others, Bispyribac-sodium fb Bentazon/MCPA and Pretilachlor/safener fb Propanil/Thiobencarb also exhibited high weed control efficacy and net benefit. All the herbicides showed high selectivity to rice plant. An attempt was made to identify the critical period of weed control (CPWC) of AERON 1 in two different seasons. The CPWC varied between seasons. Based on the 5% yield loss level, the CPWC in main and off seasons were 7 to 49 and 7 to 53 days after seeding (DAS), respectively, while at 10% yield loss level, the same were 23 to 40 and 21 to 43 DAS, respectively. To develop an integrated weed management package, weed competitive rice variety AERON 1, higher seeding rate of 300 seeds/m^2 and seed priming by Zappa® were incorporated. As a consequence of integrating different agronomic practices, lower weed pressure and higher weed control efficacy were evident in this study compared to the previous study. Weed management through Cyhalofop-butyl + Bensulfuron or Bispyribac-sodium or Propanil/Thiobencarb fb Bentazon/MCPA emerge as highly effective and most economic package. Application of Pretilachlor/safener fb Propanil/Thiobencarb fb Bentazon/MCPA also may be considered. Despite being less remunerative, spraying with any of the aforesaid early-post emergence herbicides in rotation followed by a manual weeding may be recommended for long-term sustainability of aerobic rice system.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

STRATEGI PENGAWALAN RUMPAI DALAM PENANAMAN PADI AEROBIK

Oleh

MD. PARVEZ ANWAR

April 2012

Pengerusi: Profesor Madya Abdul Shukor Juraimi, PhD

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Padi aerobik, satu sistem pengeluaran padi yang menjimatkan kadar penggunaan air sangat terkesan oleh persaingan rumpai, memerlukan strategi pengurusan rumpai yang efectif. Oleh itu, kajian telah dijalankan untuk membangunkan sistem pengurusan rumpai bersepadu yang lebih komprehensif untuk sistem penanaman padi aerobik. Tiga belas germplasma padi telah dinilai berdasarkan kebolehannya menyekat persaingan rumpai dan pengeluaran hasil dalam keadaan tanah aerobik. Germplasma padi mempunyai perbezaan yang ketara dari segi kebolehan menyekat persaingan rumpai dan pengeluaran hasil. AERON 1 menunjukkan kebolehan menyekat rumpai dan potensi hasil yang tinggi, diikuti rapat oleh AERON 4. Dua kaedah penanaman serta tiga kadar semaian telah diuji untuk mengenalpasti kaedah penanaman dan kadar semaian yang sesuai dari segi menyekat rumpai dan hasil Aeron 1. Kepadatan dan berat kering rumpai berkurang secara berkala dengan peningkatan kadar semaian tetapi ia juga bergantung kepada kaedah penanaman. Semaian baris memberikan hasil yang lebih tinggi jika dibandingkan

dengan semaian tabur terus. Peningkatan kadar semaian sehingga 300 biji/m^2 didapati berkesan mengurangkan tekanan rumpai tanpa menjejaskan hasil padi. Eksperimen telah dilakukan untuk mengkaji potensi penggunaan keadah pengerapan biji benih sebagai salah satu cara pengurusan rumpai. *Priming* biji benih boleh meningkatkan percambahan, kebolehan menyekat rumpai dan hasil AERON 1. *Priming* Zappa® adalah yang terbaik dari segi menyekat pertumbuhan rumpai dan pengeluaran hasil. Dalam percubaan racun rumpai, formulasi lapan jenis racun telah digunakan dalam pelbagai kombinasi. Kebanyakan racun rumpai dapat mengawal rumpai dengan sangat baik. Dari segi keberkesanan kawalan rumpai dan kos yang efektif, Cyhalofop-butyl + Bensulfuron diikuti oleh Bentazon/MCPA memberikan kawalan rumpai yang terbaik, dan merupakan kombinasi racun rumpai yang menjimatkan kos. Selain itu, Bispyribac-sodium diikuti oleh Bentazon/MCPA dan Pretilachlor/safener diikuti oleh Propanil/Thiobencarb juga menunjukkan keberkesanan kawalan rumpai dan keuntungan bersih yang tinggi. Kesemua racun rumpai yang digunakan juga menunjukkan selektiviti yang tinggi terhadap padi. Kajian juga telah dijalankan untuk mengenalpasti tempoh kritikal untuk kawalan rumpai (CPWC) bagi AERON 1 dalam tempoh dua musim yang berbeza. Tempoh kritikal kawalan rumpai adalah berbeza di antara musim. Berdasarkan tahap 5% kehilangan hasil, tempoh kritikal kawalan rumpai musim utama adalah di antara 7 hingga 49 hari selepas tanam, manakala bagi luar musim adalah di antara 7 hingga 53 hari selepas tanam. Bagi tahap 10% kehilangan hasil untuk musim utama adalah 23 hingga 40 hari selepas tanam manakala bagi luar musim adalah 21 hingga 43 hari selepas tanam. Bagi membangunkan satu pakej pengurusan rumpai bersepadu germplasma yang kompetetif AERON 1, kadar semaian yang tinggi iaitu 300 biji/m^2 dan *priming* Zappa®

telah digabungkan. Hasil gabungan amalan agronomi yang berbeza ini, menunjukkan tekanan rumpai adalah lebih rendah dan kebolehan menyekat rumpai lebih tinggi di dalam kajian ini berbanding kajian sebelumnya. Pengurusan rumpai menerusi penggunaan Cyhalofop-butyl + Bensulfuron atau Bispyribac-sodium atau Propanil/Thiobencarb diikuti dengan Bentazon/MCPA merupakan pakej yang paling efektif dan ekonomi. Penggunaan Pretilachlor/safener diikuti dengan Propanil/Thiobencarb diikuti dengan Bentazon/MCPA boleh juga dipertimbangkan. Walaupun kurang menguntungkan, penggunaan racun rumpai tersebut di awal percambahan secara bergilir-gilir diikuti merumpai secara manual pada 30 hari selepas tanam boleh dicadangkan untuk pengekalan jangka masa panjang bagi sistem padi aerobik mampan.

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Md. Parvez Anwar

UPM Serdang, Malaysia

April 2012

I certify that an Examination Committee has met on 03/04/2012 to conduct the final examination of Md. Parvez Anwar on his PhD thesis entitled "**Integrated Weed Management in Aerobic Rice Production"** 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 Doctor of Philosophy.

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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.

MD. PARVEZ ANWAR

Date: 3 April 2012

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LIST OF ABBREVIATIONS

ACB	Above ground crop biomass
AYL	Accepted yield level
CGR	Crop growth rate
CPWC	Critical period of weed control
DAS	Days after seeding
DF	Days to flowering
DM	Days to maturity
E	Emergence
EVV	Early visual vigor
fb	Followed by
FGN	Filled grains number/panicle
GDD	Growing degree days
GFP	Grain filling percentage
GI	Germination index
GP	Germination percentage
H	Harvest
HG	Heading
HGR	Height growth rate
HI	Harvest index
IWM	Integrated weed management
LAI	Leaf area index
LSD	Least significant difference
MGT	Mean germination time
MW	Manual weeding
PE	Plant erectness
PI	Panicle initiation
PH	Plant height
PL	Panicle length

PN	Panicle numbers
PW	Panicle weight
RCBD	Randomized complete block design
RD	Relative density
RDW	Relative dry weight
RYL	Relative yield loss
SAS	Statistical analysis system
SDR	Summed dominance ratio
SPAD	Silicon photon activated diode
SVI	Seedling vigor index
TA	Tillering ability
TGD	Total growth duration
TSW	Thousand-seed weight
T_{50}	Time for 50% germination
WAS	Weeks after seeding
WC	Weed competitiveness
WCE	Weed control efficiency
WD	Weed density
WDW	Weed dry weight
WR	Weed rating
WSA	Weed suppressive ability
WT	Weed tolerance
YOC	Yield increase over control

CHAPTER 1

INTRODUCTION

1.1 Project background

Rice (*Oryza sativa* L.) is the leading cereal of the world (Ashraf *et al*., 2006), and more than half of the human race depend on rice for their daily sustenance (Chauhan and Johnson, 2011a). It is the primary source of income and employment for more than 100 million households in Asia and Africa (FAO, 2004a). In Malaysia, rice is the staple food and third most important crop after oil palm and rubber (Karim *et al*., 2004). World rice demand is projected to increase by 25% from 2001 to 2025 to keep pace with population growth (Maclean *et al*., 2002), and therefore, meeting ever increasing rice demand in a sustainable way with shrinking natural resources is a great challenge.

By tradition, rice had been cultivated in flooded conditions mostly for water availability and efficient weed management (Bouman, 2003). Rice is a profligate user of water, and it alone consumes about 30% of world freshwater consumption and more than 45% of total freshwater used in Asia (Barker *et al*., 1999). For the last few decades, sustainability of water resources has been a global challenge (Juraimi *et al*., 2010). Water scarcity in agriculture is looming because of declining water availability resulted from over consumption, pollution and increased competition from other sectors (IWMI, 2000; Duda and El-Ashry, 2000). It is anticipated that by 2025, 17 million ha of irrigated rice areas may enjoy “physical water scarcity” and 22 million ha areas may subject to “economic water scarcity" in Asia (Bouman and Tuong, 2001). Therefore, flood-irrigated rice cultivation is no more feasible from practical view point, and finding ways of living with water scarcity deems necessary. A number of water saving technologies for rice production have been developed which include saturated soil culture (Borell *et al*., 1997), alternate wetting and drying (Li, 2001; Tabbal *et al*., 2002), ground cover system (Lin *et al*., 2002) and system of rice intensification (Stoop *et al*., 2002). But, in most of those systems, water losses still remain high. A fundamentally different approach to grow rice like an upland crop would be a suitable alternative (Tuong *et al.*, 2005). A new concept of growing rice termed as 'Han Dao' in Chinese or 'aerobic rice' at the IRRI (Bouman, 2003) was pioneered in China and Brazil. Aerobic rice cultivation is a production system, which involves the growing rice in well-drained, nonpuddled, and nonsaturated soils (aerobic soil) without ponded water, and thus eliminates surface runoff, percolation and evaporation losses (Singh and Chinnusamy, 2006). A true aerobic rice cultivar produces high yield, minimizes water use up to 50% (Tuong and Bouman, 2003) and boosts up water productivity by around 200% (Wang *et al*., 2002) compared to lowland rice.

Weed is as old as agriculture, and from the very beginning farmers realized the interference of weed with crop productivity (Ghersa *et al.,* 2000), which led to the coevolution of agroecosystems and weed management (Ghersa *et al*., 1994). Weeds are the greatest yield-limiting constraint to rice (WARDA, 1996). The risk of yield loss from weeds in direct-seeded rice is greater than transplanted rice (Rao *et al*., 2007). Ramzan (2003) reported yield reduction up to 48, 53 and 74% in transplanted, direct seeded flooded and direct seeded aerobic rice, respectively. Aerobic rice is subject to much higher weed pressure with a broader weed spectrum than flood-irrigated rice (Balasubramanian and Hill, 2002). In tropic, average rice yield losses from weeds is 35% (Oerke and Dehne, 2004), while in aerobic rice, yield penalty is as high as 50-91% (Rao *et al*., 2007). Sunil *et al*. (2010) as stated, season-long weed competition in aerobic rice may cause yield reduction up to 80%. Jayadeva *et al.* (2011), on the other hand, reported complete failure of crops due to weeds in aerobic rice. Dry direct seeded aerobic rice germinates simultaneously with weeds resulting in no 'head start' over weeds and no size differential with weeds (Rao *et al*., 2007). At the same time, aerobic rice lacks a standing water layer to suppress weeds in the early stage of crop (Moody, 1983), which makes it more vulnerable to weeds. Therefore, an efficient, cost- effective and eco-friendly weed management strategy is crucial for the sustainability of this water-wise technology.

1.2 Project development

Weed problem is sought to be addressed from two basic points of view: weed control and weed management (Ghersa *et al*., 2000). Control approach only emphasizes on reduction of weed pressure; management approach, by contrast, focuses on keeping weed infestation at a level compatible with environmentally and economically sustainable production (Radosevich *et al*., 1997). However, different weed control options are available for rice. Physical control are eco-friendly but tedious and labor-intensive (Roder and Keobulapha, 1997); other problems include delayed weeding due to unavailability of labor (Johnson, 1996), damage to the rice seedlings and mistaken removal of rice seedlings (Moody and Cordova, 1985). Biological control by using different bio-agents

(Smith, 1992) and mycoherbicides (Thi *et al*., 1999) are practiced in irrigated lowland rice, but these may not be effective under aerobic soil conditions. Chemical control, on the contrary is the most effective, economic and practical way of weed management (Marwat *et al*., 2006; Hussain *et al*., 2008). Many researchers working on weed management in direct seeded rice opined that herbicide may be considered to be a viable alternative/supplement to hand weeding (Mahajan *et al*., 2009; Pacanoski and Glatkova, 2009; Chauhan and Johnson, 2011a). In China, aerobic rice cultivation is completely dependent on herbicides (Wang *et al*., 2002). But, intensive use of herbicides may result in development of resistant weed biotypes (Fischer *et al*., 2000; Heap, 2006; Rahman *et al*., 2010), crop phytotoxicity (Begum *et al*., 2008a) and public health hazard (Phuong *et al*., 2005). The other option left is cultural weed control through adoption of different agronomic practices including tillage (Cadrina *et al*., 2002; Rao *et al*., 2007), competitive cultivar (Fischer *et al*., 2001; Zhao *et al*., 2006a), seeding density (Ottis and Talber, 2005; Guillermo *et al*., 2009), water management (Hill *et al.*, 2001; Rao *et al*., 2007), fertilizer management (Buhler, 2002; Blackshaw *et al*., 2004), seed invigoration (Harris *et al*., 2002; Ghiyasi *et al*., 2008), mulching (Singh *et al*., 2007a), crop rotation (Cadrina *et al*., 2002; Shrestha *et al*., 2002) and so on. Although those agronomic tools help increase competitive ability of crop against weeds (Liebman *et al*., 2001) and at the same time are eco-friendly and economic, but may not provide acceptable level of weed control especially under aerobic soil conditions where weed pressure is very high.

A single weed control approach may not be able to keep weeds below the threshold level of economic damage, and may results in shift in the weed flora, resistance development and environmental hazard. Adoption of diverse technology is therefore essential for weed management because weed communities are highly responsive to management practices (Buhler *et al*., 1997). Besides, farmers are now becoming increasingly interested in more inclusive weed management strategy to reduce herbicide dependence (Blackshaw *et al*., 2005). Therefore, while addressing environmental concern, all the methods that are ecologically and economically justifiable should be integrated in a comprehensive way-known as integrated weed management (IWM). The IWM involves the selection, integration, and implementation of effective weed control means with due consideration of economics, environmental, and sociological consequences (Buchanan, 1976). Concern over long-term efficacy of herbicide dependent weed management has reinforced the need for IWM (Wyse, 1992). A substantial impact of IWM on rice farming has been documented by many researchers (Ho *et al*., 1990; Azmi and Baki, 2002; Sunil *et al*., 2010; Jayadeva *et a*l., 2011). So far, however, little attention has been paid to sustainable weed management in aerobic rice which demands research on integrated weed management through combining possible agronomic practices with herbicides to make aerobic rice technology a popular as well as sustainable one.

1.3 Objectives

The research program was undertaken to develop an integrated weed management strategy for the sustainability of aerobic rice in water limiting environments. The specific objectives of the study are pointed below:

1. To identify promising aerobic rice variety for weed-competitiveness and yield potential

2. To elucidate the role of rice seeding method and rate in suppressing weeds
3. To evaluate selected seed priming techniques as a tool for weed suppression
4. To estimate the critical period of weed control to rationalize and optimize inputs required for weed control
5. To identify potential herbicides with alternate modes of action for efficient weed management, and
6. To formulate an integrated weed management technology combining agronomic practices with herbicides for the sustainability of aerobic rice system.

1.4 Thesis outline

The dissertation starts with chapter 1 which contains statement of the problem, formulation of the hypothesis and objectives of the study. A thorough review of the literature on rice ecosystems, water saving rice production technologies, weed problem in rice and its management options was done in chapter 2. Weed problem in aerobic rice was highlighted and integrated weed management with special emphasis on agronomic practices was also discussed to justify the present work. Chapter 3 describes the general materials and methodology of the study. Chapter 4 represents a comparison of weed competitiveness and yield potential of selected rice varieties grown in aerobic soil conditions. Exploitation of rice seeding method and rate in minimizing weed pressure under aerobic soil conditions has been discussed in chapter 5. Chapter 6 explores the feasibility of adopting seed priming as a component of integrated weed management for aerobic rice. Critical period of weed control for aerobic rice were determined and discussed in chapter 7. Chapter 8 appraises the weed control efficacy, rice phytotoxicity and cost effectiveness of different herbicides under aerobic soil conditions. In chapter 9, an attempt was made to integrate the best agronomic package with potential herbicides for sustainable weed management in aerobic rice. Chapter 10 portrays summary and the conclusions of this project with recommendation for future work. A list of publications originated from the study appears at the end of this dissertation.

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