UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF SINGLE SEEDLING NURSERY TRAY FOR THE SYSTEM OF RICE INTENSIFICATION

USMAN BASHAR ZUBAIRU

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By

USMAN BASHAR ZUBAIRU

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

July 2013

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DEDICATION

This thesis has been dedicated to the entire Muhammad Basharu family, may God Almighty continue to shower His mercies and blessings abundantly on the family.

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

DEVELOPMENT OF SINGLE SEEDLING NURSERY TRAY FOR THE SYSTEM OF RICE INTENSIFICATION

By

USMAN BASHAR ZUBAIRU

July 2013

Chairman: Aimrun Wayayok, PhD

Faculty: Engineering

One of the main problems in the adaption of the System of Rice Intensification (SRI) techniques is high labor requirements for manual planting of the single seedling in the field. Seedling quality and transplanting skills play a vital role in promoting optimum yield. However, the existing seedling raising methods remain a challenging constraint among SRI practitioners due to the absence of a mechanized adaptation of SRI planting and spacing standards. Ironically, farmers are forced to pay for replanting hence increasing the production cost. Therefore, this study was intended to create modern techniques for increasing the quality and transplanting potentials of rice seedling by improving SRI nursery and reducing seedlings transplanting shock.

Prior to designing of SRI nursery tray, a study was conducted on the physical properties of MR219 rice seed to determine the basic parameters of the seed. These properties were evaluated as a function of moisture content at 14.3, 18.9 and 22.5% dry basis. The results revealed that length, width and thickness increased with increasing moisture content from 9.6 to 10.2, 2.2 to 2.3 and 1.9 to 2.0 mm, respectively. Similarly, M_{1000} increased from 27.1 to 29.9g as well as arithmetic and geometric mean diameters from 4.8 to 4.9 and 3.4 to 5.7 mm. Bulk density, sphericity, and surface area increased with moisture content from 517.7 to 543.5 kg/m^3, 0.358 to 0.362% and 37.2 to 42.6 mm^2 respectively. A decrease was observed for true density (1244.6 to 1197.5 kg/m^3) and porosity (58.4 to 54.6) as seeds rewetting increased. These technical information were used in SRI tray design and development.

The single seedling nursery tray of rectangular shape was developed with length 635 mm, width 335 mm and height 40 mm with open top and square growing cavities of 15 x 15 mm separated by a thickness of 1mm with 30 mm height. A sliding base plate 635mm long, 332 mm wide and 4mm thick, served as a valve in holding and placing seedling for transplanting into the field. The tray was capable of producing 924 vigorous and viable independently separated seedlings for transplanting singly upon SRI spacing standard.

Seed selection was conducted before sowing as every seed matters when using the SRI tray. The experiment revealed that 100% germination after ten days was obtained from the sunken MR219 seeds collected in 80 g/L of NaCl solution. These values reported a decrease in germination (85%) with increasing NaCl concentration (120 g/L), with least germination vigor of 62% in water 3 days after sowing. A 100% seed sprouting was also recorded from the selected seeds when primed for six hours.

A SRI seed picker was also developed to place the sprouted seeds in SRI tray. It was made with 924 cone shape seed pickers for attachment of individual seeds and dropping the seeds into 924 SRI tray holes. The fastest picking and dropping level was reported at 150 g/L of tapioca and water solution.

Three different media, namely Soil + Burnt husk (1:1) as M_1, Soil + Compost (1:1) as M_2 and compost alone as M_3 were used to evaluate the growth performances after ten (10) days. The measured parameters were seedling height (SH), leaf length (LL), leaf number (LN), root length (RL) and loosening index (LI) from the SRI tray and compared with seedlings from the conventional tray. The SAS and Duncanôs mean results revealed that M_2 had the highest significant values for SH, LL and LI with the mean values of 15.56 cm, 10.93 cm and 75 seconds but reported a decrease on RL (8.93 cm) when compared with M_1 and M_3 having RL values of 9.23 and 10.27cm, respectively. Likewise, M_1 indicated a drop on SH with mean value of 14.53cm and also LL with the mean value of 10.03 cm but reported a mean value of 9.23 cm on RL after M_3.

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

PEMBANGUNAN DULANG TAPAK SEMAIAN BENIH TUNGGAL BAGI SISTEM PENANANMAN PADI INTENSIFIKASI

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Salah satu masalah utama dalam adaptasi teknik Sistem Padi SRI adalah keperluan buruh yang tinggi untuk penanaman anak benih tunggal secara manual di ladang. Kualiti anak benih dan kemahiran mencedung memainkan peranan penting dalam mempromosikan hasil optimum. Walau bagaimanapun, kaedah pembesaran anak benih masih ada kekangan mencabar di kalangan pengamal SRI kerana ketiadaan jentera penanaman padi SRI yang sesuai dan menjaga jarak mengikut piawaian. Oleh itu, kajian ini bertujuan untuk mewujudkan teknik moden bagi peningkatan kualiti dan potensi penanaman anak benih padi dengan meningkatkan kualiti di tapak semaian SRI dan mengurangkan kejutan terhadap penanaman anak benih.

Sebelum merekabentuk dulang tapak semaain SRI, satu kajian telah dijalankan ke atas ciri fizikal biji benih padi MR219 untuk menentukan parameter asas biji benih. Ciri-ciri ini telah dinilai berasaskan fungsi kandungan kelembapan pada 14.3, 18.9 dan 22.5%

asas kering. Keputusan menunjukkan bahawa panjang, lebar dan ketebalan meningkat dengan peningkatan kadar kandungan lembapan 9.6 kepada 10.2mm, 2.2 kepada 2.3mm dan 1.9 kepada 2.0mm, masing-masing. Begitu juga, M_{1000} meningkat daripada 27.1 kepada 29.9g serta purata diameter aritmetik dan geometri dari pada 4.8 kepada 4.9mm dan 3.4 kepada 5.7 mm. Ketumpatan pukal, sferisiti, dan kawasan permukaan meningkat dengan kandungan kelembapan dari 517.7 kepada 543.5 kg/m^3, 0.358 kepada 0.362% dan 37.2 kepada 42.6 mm^2, masing masing. Penurunan diperhatikan untuk kepadatan sebenar (1244.6 kepada 1197.5 kg/m^3) dan keliangan (58.4 ï 54.6%) selama pembasahan biji meningkat. Maklumat teknikal ini telah digunakan dalam merekabentuk dan pembangunan dulang SRI.

Dulang tapak semaian anak benih tunggal berbentuk segi empat tepat telah dibangunkan dengan saiz panjang 635mm, lebar 335 mm dan tinggi 40 mm dan terbuka di atas bagi mendapat rongga persegi tanaman seluas 15 x 15 mm dan dipisahkan oleh dinding ketebalan 1 mm dan tinggi 30 mm. Plat gelongsor panjang 635 mm, lebar 332 mm dan tebal 4 mm, berkhidmat sebagai injap dalam memegang dan meletakkan anak benih untuk ditanam ke ladang. Dulang itu mampu menghasilkan 924 benih yang kuat dan berdaya maju secara bebas dipisahkan untuk ditanam secara tunggal mengikut jarak piawaian SRI.

Pemilihan benih telah dijalankan sebelum menyemai benih kerana setiap biji benih adalah diambil kira apabila menggunakan dulang SRI ini. Eksperimen menunjukkan bahawa percambahan 100% selepas sepuluh hari telah diperolehi daripada biji benih MR219 yang tenggelam dalam 80g/L cecair NaCl. Nilai-nilai ini menunjukan penurunan dalam percambahan (85%) apabila kepekatan NaCl ditingkatkan (120g/L), dan percambahan benih yang kuat yang paling sikit iaitu 62% percambahan pada 3DAS. Percambahan 100% juga dicatatkan dari benih yang telah dipilih apabila diperam selama enam jam.

Peletak biji SRI juga telah dibangunkan untuk meletakkan benih tumbuh di dulang SRI. Ia telah dibuat dengan 924 pemegang biji benih berbentuk kon untuk meletak satu persatu biji benih dan menjatuhkan biji benih ke dalam 924 lubang dulang SRI. Yang paling cepat memegang dan menjatuhkan dilaporkan pada 150g/L cecair tepung ubi kayu di larut dalam air.

Tiga media yang berbeza, iaitu tanah + sekam batar (1:1) sebagai M_1, tanah + kompos (1:1) sebagai M_2 dan kompos sahaja sebagai M_3 telah digunakan untuk menilai prestasi pertumbuhan pada sepuluh (10) hari. Parameter yang diukur ialah ketinggian anak benih (SH), panjang daun (LL), bilangan daun (LN), panjang akar (RL) dan indeks kelonggaran (LI) dari dulang SRI dibandingkan dengan benih dari dulang konvensional. Keputusan yang diperolehi daripada SAS dan Duncan mendedahkan bahawa M_2 mempunyai nilai tertinggi yang ketara bagi SH, LL dan LI dengan nilai purata 15.56 cm, 10.93 cm dan 75 saat, masing masing, tetapi melaporkan penurunan RL (8.93 cm) apabila dibandingkan dengan M_1 dan M_3 yang mempunyai nilai RL 9.23 dan 10.27 cm, masing masing. Sementara M_1 menunjuk penurunan bagi SH dengan nilai purata 14.53 cm dan juga LL yang mempunyai nilai purata 10.03 cm tetapi melaporkan nilai purata 9.23 cm bagi RL iaitu selepas M_3.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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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 any other institution.

USMAN BASHAR ZUBAIRU

Date: 31ST July 2013

TABLE OF CONTENTS

	Page
ABSTRACT	iii
ABSTRAK	vi
ACKNOWLEDGEMENTS	ix
APPROVAL	x
DECLARATION	xii
LIST OF TABLES	xvii
LIST OF FIGURES	xix
LIST OF ABBREVIATIONS	xxi

CHAPTER

1	**INTRODUCTION**	
	1.1 Background	1
	1.2 Problem Statement	6
	1.3 Objectives of the Study	6
	1.4 Scope and Limitations	7
	1.5 Thesis layout	7
2	**LITERATURE REVIEW**	
	2.1 Innovative Rice Cultivation	9
	2.2 SRI global mission	10
	2.2.1 Concepts	10
	2.2.2 Benefits	11
	2.2.3 Constraints	12
	2.3 Seed	12
	2.3.1 Parts of rice seed	13
	2.3.2 Seed quality and Nutritional value	14
	2.3.3 Characteristics of quality seed	15
	2.3.3.1 Purity	15
	2.3.3.2 Seed Viability	16
	2.3.4 Physical properties of MR219 rice seeds	17
	2.4 Seed germination	17
	2.4.1 Breaking the dormancy	19
	2.4.2 Seed cleaning	19
	2.4.3 Seed soaking method	20
	2.4.4 Seed priming	21
	2.4.5 Pre-germination	22
	2.5 Rice Seedling	23
	2.5.1 Seedling quality	24

2.5.2 Seedling media 25
2.5.3 Rice seedling soil management 25
2.5.3 Rice seedling water management 26
2.6 Rice Seedling Nursery methods 27
2.8 Summary 29

3 MATERIALS AND METHODS
3.1 Rice Seedling Preparation 31
3.2 Physical properties of MR219 rice seed 33
3.3 SRI Single Seedling Nursery tray design specifications 39
3.3.1 Chronology of events of the tray development 39
3.3.2 Basic dimensions of the main tray 39
3.3.3 Basic dimensions of the sliding base plate 42
3.3.4 Material 43
3.3.5 Weight 44
3.3.6 Seedling number per tray 44
3.4 Development of SRI Single Seedling tray 45
3.4.1 Setting of the prototype 45
3.4.2 Procedure for development of the tray 46
3.5 Planting Procedure/ testing of developed SRI Single Seedling tray 46
3.5.1 Selection/ Sorting of MR219 rice seed 46
3.5.2 Pre ï germination of MR219 rice seed 48
3.5.3 Site Preparation 49
3.5.3.1 Seedling nursery per planting area 49
3.5.3.2 Seeds volume per planting area 49
3.5.3.3 Seedling number per SRI tray 50
3.5.3.4 SRI tray number per planting area 51
3.5.4 Placing seed into tray hole 51
3.5.5 SRI seed picker specifications 52
3.5.6 SRI seed picker operational principle 52
3.6 Experimental seedling media 54
3.7 Monitoring of seedling establishment 54
3.7.1 Experimental analysis 54
3.7.2 Samples and sample preparation 55
3.7.3 MR219 growth performance evaluation 56

4 RESULTS AND DISCUSSION
4.1 Introduction 58
4.2 Physical properties of MR219 seed 58
4.2.1 Seed dimensions 59
4.2.2 Arithmetic and geometric mean diameters, M_{1000} seed mass, surface area and sphericity 60
4.2.3 Bulk and true densities 62
4.2.4 Porosity 63

4.2.5 Static coefficient of frictions 64
4.3 Physical characteristics of the developed SRI Single Seedling Nursery Tray 65
4.3.1 Basic dimensions 65
4.3.2 Planting cavities 67
4.3.3 Sliding base plate 67
4.4 Criteria and conceptual design of SRI single seedling tray 68
4.4.1 Design criteria 68
4.4.2 Design performance 68
4.5 Seed selection using salt and water solution 69
4.6. Pre ï germination 71
4.6.1 Seed soaking 71
4.6.2 Seed priming 71
4.7 Germination test 72
4.8 Nursery preparation 75
4.8.1 Seedling number per SRI tray 75
4.8.2 Seedling number per planting area 75
4.8.3 Volume of seed per planting area 76
4.8.4 Volume of media per SRI tray 76
4.8.5 Number of SRI per area 77
4.8.6 Nursery area per hectare 78
4.9 The most suitable media for SRI Single Seedling 79
4.9.1 Media selection 79
4.9.2 Seed placement with SRI seeder 79
4.10 MR219 Seedling growth characteristics 81
4.10.1 Seedling height 83
4.10.2 Leaf length 86
4.10.3 Root length 88
4.10.4 Leaf number 90
4.10.5 Loosening index 90
4.11 Comparison of the developed SRI tray with existing trays 91
4.12 Advantages of SRI single seedling tray over other methods 95
4.13 Seedling transfer to paddy field 96
4.13.1 Manual method 96
4.13.2 Mechanical method 97

5 CONCLUSIONS AND RECOMMENDATIONS
5.1 Conclusions 99
5.2 Recommendations for future research 101

REFERENCES	102
APPENDICES	115
BIODATA OF STUDENT	129
LIST OF PUBLICATIONS	130

LIST OF TABLES

Table		Page
2.1	Summary of rice nursery types	29
3.1	SRI single seedling nursery tray specifications	42
3.2	Cutting specifications of PVC pieces of SRI tray	45
3.3	SRI seed picker design specifications	53
3.4	Growth evaluation record sheet	55
4.1	Mean and Standard error for dimensions, surface area, 1000 seed mass and sphericity	61
4.2	Moisture content with bulk and true densities, porosity, coefficient of friction and repose angle	65
4.3	Complete design specification of SRI tray	67
4.4	Seed sorting technique with 100 seeds	70
4.5	Germination rate with respect to seed sorting	74
4.6	Summary on basic output to nursery preparation	78
4.7	SRI tray versus conventional on seedling height 10 DAS	84
4.8	Analysis of variance on seedling height 10 DAS	85
4.9	Duncanôs means grouping on seedling growth performance 10 DAS	85
4.10	SRI tray versus conventional on leaf length 10 DAS	87
4.11	Analysis of variance on leaf length 10DAS for SRI tray	87
4.12	SRI tray versus conventional on root length 10 DAS	88
4.13	Analysis of variance on root length 10 DAS	89
4.14	Analysis of variance on loosening index 10 DAS	91

4.15 Characteristics of rice seedling growth 3 DAS in SRI and Conventional trays 93

4.16 Characteristics of rice seedling growth 10 DAS in SRI and Conventional trays 93

4.17 SRI nursery versus existing nurseries preparation 94

4.18 Comparative tray design specifications categories 94

LIST OF FIGURES

Figure		Page
1.1	More than 50 Countries have tried SRI as of 2012	3
2.1	Cross sectional parts of rice seed	14
2.2	Morphological growing stages of rice seed	18
2.3	Schematic parts of rice seedling	24
2.4	Schematic growing stages of rice seedling	27
2.5	Types of seedling nurseries	28
3.1	Methodology flow chart	32
3.2	MR219 rice basic dimensions sample readings	35
3.3	Mass of 100 seeds	36
3.4	Perspective view of single seedling nursery tray	40
3.5	Front view of single seedling nursery tray	40
3.6	Bottom perspective view of the single seedling tray	41
3.7	Top plane view of single seedling tray	41
3.8	Sliding base plate for single seedling tray	42
3.9	Main tray and sliding base plate	43
3.10	Assembled single seedling nursery tray with sliding base	46
3.11	Floating egg at various NaCl concentrations	48
3.12	Rice seed selection (sunken and floated)	48
3.13	SRI seed picker for seed placement	53
3.14	Growing media arrangement in RCBD design	56
4.1	Basic dimensions versus Moisture content	60

4.2	Means of seed dimensions on moisture content	62
4.3	Effect of moisture content on bulk and true density	63
4.4	Effect of moisture content on porosity	64
4.5	A prototype SRI nursery tray developed using perspective PVC	66
4.6	Seed sorting technique	70
4.7	Primed MR219 rice seeds	72
4.8	Germination test sample	73
4.9	Graph of germination rate for various NaCl concentration used in seed sorting	74
4.10	Manually fabricated SRI seed picker	80
4.11	Seed placement into SRI tray	81
4.12	Sowing and seedling establishment	82
4.13	Sample of SRI tray seedling (10 DAS)	82
4.14	Effect of media on seedling height with SRI tray	84
4.15	Effect of media on seedling height with conventional tray	85
4.16	Effect of media on leaf length with SRI tray	86
4.17	Effect of media on leaf length with conventional tray	86
4.18	Effect of media on root length with SRI tray	89
4.19	Effect of media on loosening index with SRI tray	91
4.20	Dropping stages of 10 DAS for field transplanting	98

LIST OF ABBREVIATIONS

UPM	-	Universiti Putra Malaysia
SRI	-	System of Rice Intensification
FAO	-	Food and Agricultural Organization
UNEP	-	United Nations Environmental Programme
ASAE	-	American Society of Agricultural Engineering
IRRI	-	International Rice Research Institute
ISTA	-	International Seed Testing Association
IWMI	-	International Water Management Institute
RKMP	-	Rice Knowledge Management Portal
AFSC	-	American Friends Service Committee
WWAP		World Water Assessment Programme
UNDESA		United Nations Department of Economic and Social Affairs
MR219		Malaysian rice variety
DAS	-	Day after sowing
ha	-	Hectare
m	-	Metre
cm	-	Centimetre
sec	-	Second
g	-	Gramme

Ů	-	Porosity
A	-	Area
PVC	-	Polyvinyl chloride
M_{1000}	-	Mass of 1000 seeds
V_s	-	Volume of seed
S_n	-	Seedling number per area
S_p	-	Spacing pattern
S_t	-	Seedling number per tray
A_t	-	Area of the tray
S_{pt}	-	Spacing pattern per tray growing cavities
T_t	-	Total number of trays per area
g/L	-	Gramme per litre
V_m	-	Volume of media
N_a	-	Nursery area
M_1	-	Soil + Burnt husk
M_2	-	Soil + Compost
M_3	-	Compost alone
T_1	-	SRI single seedling nursery tray
T_2	-	Conventional tray
SH	-	Seedling height

LL	-	Leaf length
LN	-	Leaf number
RL	-	Root length
LI	-	Loosening index

CHAPTER 1

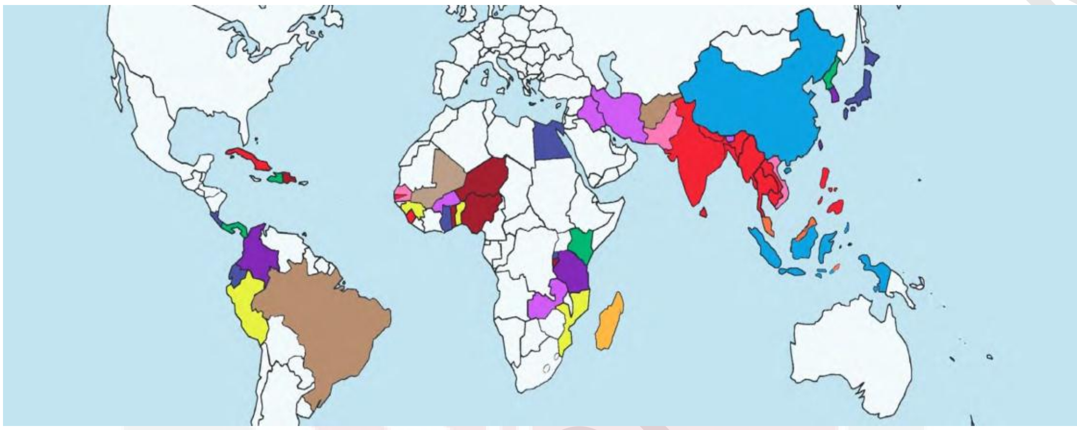
INTRODUCTION

1.1 Background

Rice (*Oryza Sativa* in Asia or *Oryza Glaberrima* in Africa), classified as a monocotyledon plant because of its behavior of producing one leaf per growth development. Rice is considered by cultural geographers as the staple food for a large part of the human population especially in Asia, Africa and some parts of Europe, America, and West Indies upon which the latter were predominantly dependent on other cereals such as millet, wheat and maize. According to FAO (2004), rice stands as a grain with third ï highest world production after wheat and maize. Smith (1998) stated that rice is the most important grain with regards to human nutrition and caloric intake, by providing more than one fifth of the calories consumed by human worldwide. This tasty and versatile grain can also be grouped as the type of crops that can be grown substantially in almost every part of the world ranging from traditional or conventional to modern or integrated methods, depending upon the availability of water, soil texture and topography of the land by given an output as lowland (rain fed or irrigated) rice, deep water or floating rice, coastal wetland rice and upland rice. These bring to the existing number of over 40,000 varieties of rice worldwide (FAO, 2012; Rajesh and Thanunathan, 2003).

Moreover, the traditional method of growing rice is usually done in the paddy fields that are mostly flooded with high level of water during the vegetative stage; seedlings are also raised with much water, in high density and transplanted at older age generally more than one month. Likewise, some damages occur during uprooting and transplanting on both the root and the stem (Misha and Uphoff, 2011). It can be clearly noticed in the traditional method as well that the seedlings are closely planted with no equal spacing considered and the weeding is not done early enough and regularly. In this method also there is a limited use of organic fertilizer, thereby mostly dependent on the use of chemical fertilizers which eventually bring poor yield as compared to the integrated methods such as System of Rice Intensification (Mishra *et al*, 2006). This system involves transplanting single young seedlings with wider spacing, carefully and quickly into the fields that are not kept continuously flooded, and whose soil has more organic matter with little or no fertilizer and is actively aerated (Uphoff *et al.*, 2010).

The System of Rice Intensification (SRI) developed in Madagascar more than 30 years ago by a French Researcher Fr. Henri de Laulanié proved to be one of the most recent agricultural innovations that modify certain practices for managing plant, soil, water and nutrients. This integrated crop management can raise, concurrently, the productivity of the land, labor, water, and capital invested in irrigated rice production (Lala n i e ô , 2 0 0 3 Uphoff *et al.*, 2010). Consequently, SRI is aimed at improving the productivity of land and water with regards to labor and capital as compared to the commonly known flooded rice production. According to Uphoff *et al*. (2011), the SRI is gaining momentum and credence as probably over 500,000 farmers are now using this method in raising their rice production, thereby reducing external inputs and production costs. Successful application of SRI indicated an increase in production by 50 ï 100% or even more thereby saving irrigated water use between 25 ï 50% with a credible saving of 80 ï 90% of seeds and also relying more on organic matter rather than chemical fertilizers. This sounds too good to be true, but the productivity of SRI methods has been validated in more than 50 countries, from China to Cuba, Peru to Philippines, Gambia to Zambia, and even in Iraq, Iran, Malaysia and many more (Figure 1.1).



2012 SRI benefits have now been seen in >50 countries of Asia, Africa, and Latin America (Cornell Univ., 2012)

Before 1999: Madagascar

1999: China, Indonesia

2000-01: Bangladesh, Cuba, Laos, Cambodia,

Gambia, India, Nepal, Myanmar, Philippines,

Sierra Leone, Sri Lanka, Thailand

2002-03: Benin, Guinea, Moz., Peru

2004-05: Senegal, Pakistan, Vietnam

2006: Burkina Faso, Bhutan, Iran, Iraq, Zambia

2007: Afghanistan, Brazil, Mali

2008: Rwanda, Costa Rica, Ecuador, Egypt, Ghana, Japan

2009: Malaysia, Timor Leste

2010: Kenya, DPRK, Panama, Haiti

2011: Colombia, Korea, Taiwan, Tanzania

2012: Burundi, Dominican Republic, Niger, Nigeria, Togo

Figure 1.1: More than 50 Countries have tried SRI as of 2012

Therefore, SRI is undoubtedly considered as an environmentally ï friendly, climate ï smart methodology that increases crop yields with fewer seeds, less water, decreased purchased inputs and often less labor (Africare, Oxfam America, & ICRISAT, 2010). Thus, contrary to some researchersô agitations that said yi increased with increase in chemical fertilizers application.

Despite all these advantages on rice, the issue of food security is still among the malingering worldôs sit ing the required demand. FAO to as (2012) estimated that a total of 870 million people worldwide were undernourished (in terms of dietary energy) between 2010 and 2011. This figure represents 12.5 percent of the global population or one in eight people. Out of these, 852 million live in developing countries, where the prevalence undernourishment is now estimated at 14.9 percent of the population. Furthermore, UNEP (2011) estimated that up to 25 percent of the world food production could be lost by 2050 the population in hunger as a result of climate change, water scarcity and land degradation. However, with this challenging situation, the Malaysian Government decided to introduce a program in 2008 tagged ñ100% 2015ì which aims at balancing the gap between the production and the population demand. Achieving these objectives can only be possible through the creation of modern techniques for ameliorating the yield which is proportional to the seedling quality and transplanting pattern. Therefore, these techniques require improvement on the current seedling raising and transplanting practices to suite SRI planting and transplanting standards.

The rice seedling nursery can broadly be seen as the technique of planting and raising young seedling to a certain level of growth for transplanting into paddy field. This leads to the production of healthier and vigorous seedling which should be short, thick and free from pests and diseases; these are the major aims of nursery management. Consequently, this can be observed through different methods and/or type of nursery setting (which depend on availability of water, seed quality as well as physical and chemical compositions of the growing medium). The most common ones are classified into groups from traditional to modern methods as spreading or broadcast, Wet-bed, Dry-bed, Mat and tray. All these methods require high volume of seeds for seedling establishment with an average of 15 ï 50 kg/ha (Balasubramanian, 2009). The labor is intensive and the nursery has to be set most of the time in the field. Likewise, seedlings are mostly ready for transplanting after 25 ï 30 days after sowing (DAS). In view of these continuing challenges mechanization of SRI nursery and transplanting techniques become imperative by designing a rice production system that can respond suitably to current food insecurity problems.

This proposed single seedling nursery tray is considered to be one of the SRI innovations thereby enhancing the production of exactly one young, delicate, undisturbed root and healthy seedling in independently separated growing cavities of 15 x 15 mm. Moreover, much emphasis was put on selecting the best seeds through physical properties and germination test conducted in various laboratories of Universiti Putra Malaysia during the period of the study prior to nursery setting as every seed matters with this tray. The produced seedlings will be transplanted to the paddy field with respect to SRI spacing pattern of 25 x 25 cm, which will eventually reduce seedling trauma, transplanting shock and damage and promote increased productivity.

1.2 Statement of Problem

The requirements of SRI system are to transplant single seedling at a very young age of 8 - 10 days after seed germination in a nursery with a very proper lining of 25 x 25cm spacing. However, the current seedling nursery practices establish traumatic seedlings resulting to roots interconnection, nutrients, water, oxygen and sunlight competition, which eventually endangers the seedling quality and low production. It also makes the transplanter to plant more than one seedling at a time as well as leaving some places unplanted thereby making farmers paying for replanting leading to increased production cost. Furthermore, these existing nursery practices brought major challenges in SRI farming as they could not soundly respond to SRI spacing and transplanting conditions. Therefore, there is a need for a new window to SRI innovative approaches by providing quality seedlings through the use of a c

nursery tray for The SRI tray should be able to produce ineò. vigorous, healthier, weeds free and roots separated seedlings through an independently separated growing cavities with low seeding density.

1.3 Objectives of the Study

The main objective of this research was to develop a new SRI nursery tray and the specific objectives were as follows:

a) To determine the physical properties of most applicable rice seed (MR219) in Malaysia to promote 100% germination when using the new SRI tray.

b) To determine the most conducive soil and water environment for individual SRI seedling to ensure a healthier seedling is produced in the new SRI tray.

c) To design and develop the most suitable rice nursery tray for growing SRI single seedling in the field.

1.4 Scope and Limitation

The scope of this research shall be to design and develop a single seedling nursery tray capable of producing good quality seedlings for direct field planting using a planting machine. The study is limited to only developing the tray to be attached to the SRI planter.

1.5 Thesis Layout

The thesis is divided into five chapters. Chapter one discusses the background on food security, seedling nursery, and SRI with regards to modern and conventional method, the problem statement, objectives as well as the scope and limitation of the work. In Chapter Two, literature review is presented on the physical properties of the MR219 rice seeds, seed germination, seedling nursery and nursery tray design. Chapter Three discusses the materials and methods used in the research. The seed selection through physical properties and germination procedures; design of the proposed tray in 3D AutoCAD and STL formats, and the printing/development of tray to SRI standards are presented. Also, detailed explanations of the procedures adopted in conducting all experiments are given. Results obtained from the experiments conducted on MR219 physical properties, seed selection, germination test and the development and testing of the SRI single seedling nursery tray on growth characteristics are presented in Chapter Four. Observations, conclusions and recommendations are presented in Chapter Five. All observations made during the conduct of the experiments, development and fabrication of the seedling tray and testing are presented in this chapter. Conclusions are drawn from the observations and finally the recommendation for further works is made.

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