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DESIGN AND DEVELOPMENT OF SRI SINGLE SEEDLING TRANSPLANTING IMPLEMENT WITH SEEDLINGS IN SEMI-DRIED CLAY MEDIA

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DESIGN AND DEVELOPMENT OF SRI SINGLE SEEDLING TRANSPLANTING IMPLEMENT WITH SEEDLINGS IN SEMI-DRIED CLAY MEDIA

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September 2016

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In rice production, seedling quality and transplanting potentials stand as a prerequisite for the proper completion of rice production operations in securing optimum yield. The overall objective of this research was to develop a transplanting implement capable of placing rice seedling singly into the field by dropping through a gated opener with respect to SRI planting and spacing conditions deprived from the existing methods of picking fingers by the conventional transplanting machines. It has been built with the aim of using seedlings established from SRI-tray of 924 separated growing cavities. It was designed with adjustable spacing options on both within and between rows of 25 cm, 30 cm and 40 cm respectively in order to suite intending SRI practitioners preference. Accordingly, it has been set to provide nine SRI spacing options (25 cm × 25 cm, 25 cm × 30 cm, 25 cm × 40 cm, 30cm × 30 cm, 30 cm × 40 cm and 40 cm × 40 cm, respectively). The performance of SRI single seedling transplanting implement was evaluated and the measured parameters were suitable growing media, planting speed, percentages of single seedling placement per hill, missing hills and multiple planting. Others include turning head, loading time, angle of repose, field capacity and field efficiency. The planting data indicated that speed of operation run at 0.18 m/s reported high significance percentage of single seedling per hill when subjected to spacing patterns of 25 × 35 cm (84%), 25 × 25 cm (81%), 30 × 30 cm (73%) and 40 × 40 cm (83%) but decreased with the increasing speed of 0.45 m/s as 53%, 56% and 72%; thus surprising stability on 40 × 40 cm of 83%. The results obtained on growing media revealed that clay with compost had the highest significance with respect to the weight of seedling (25.3 g) giving the loosening index of 66 seconds and the planting depth of 16 mm when transplanting in the field. The results obtained from field capacity and field efficiency revealed that when the tractor was maintained to 0.18 m/s, the field capacity and field efficiency reported the values of 1.29 ha/hr and 79.5%, respectively but when

the speed was fixed or increased to 0.45 m/s these values changed to 1.55 ha/hr and 75%.

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

REKABENTUK DAN PEMBANGUNAN IMPLEMEN JENTANAM ANAK BENIH TUNGGAL SRI YANG DISEMAI DALAM MEDIA LIAT SEPARA-KERING

Oleh

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Dalam pengeluaran beras, kualiti anak benih dan potensi pemindahan menjadi syarat utama bagi operasi pengeluaran beras untuk mendapatkan hasil yang optimum. Objektif keseluruhan kajian ini adalah untuk membangunkan implemen pemindahan yang mampu meletakkan anak benih padi secara tunggal ke sawah dengan menjatuhkan melalui pembukaan pintu penanaman mengikut jarak yang disyaratkan oleh SRI berbanding kaedah yang sedia ada iaitu mesin pemindahan konvensional yang berbentuk jari pemetik. Ia telah dibina dengan tujuan untuk menggunakan benih yang telah dibesarkan daripada dulang SRI -yang mempunyai 924 ruang lubang yang berasingan. Ia telah direka dengan pilihan jarak yang boleh dilaraskan pada kedua-dua jarak di dalam dan di antara baris iaitu 25 cm, 30 cm dan 40 cm masing-masing untuk memenuhi hasrat pengamal SRI. Dengan itu, ia dapat menyediakan sembilan pilihan jarak tanaman SRI (25 cm × 25 cm, 25 cm × 30 cm, 25 cm × 40 cm, 30 cm × 30 cm, 30 cm × 40 cm dan 40 cm × 40 cm, masing-masing). Prestasi implemenpemindahan anak benih tunggal SRI telah dinilai dan parameter yang diukur adalah media tanaman yang sesuai, kelajuan penanaman, peratusan penempatan anak benih tunggal pada setiap rumpun, rumpun hilang dan penanaman anak benih yang berbilang. Lain-lain parameter termasuk pusingan kepala, tempoh masa muatan, sudut terbaring, keupayaan ladang dan kecekapan ladang. Data penanaman menunjukkan bahawa pada kelajuan operasi 0.18 m / s melaporkan peratusan anak benih tunggal setiap rumpun adalah tinggi dengan ketara apabila ditanamkan pada jarak 25 × 35 cm (84%), 25 × 25 cm (81%), 30 × 30 cm (73%) dan 40 × 40 cm (83%) tetapi ia menurun apabila kelajuan semakin meningkat iaitu 0.45 m / s sebanyak 53%, 56% dan 72%; kestabilan itu mengejutkan pada 40 × 40 cm iaitu sebanyak 83%. Keputusan yang diperolehi dari media pertumbuhan mendedahkan bahawa tanah liat dengan kompos mempunyai berat anak benih (25.3 g) ayng amat tinggi dengan ketara, ia memberi indeks lepasan sebanyak 66 saat dan

kedalaman penanaman ialah 16 mm apabila dipindah ke ladang. Keputusan yang diperolehi daripada keupayaan ladang dan kecekapan ladang mendedahkan bahawa apabila traktor dikekalkan kelajuan pada 0.18 m / s, keupayaan ladang dan kecekapan ladang dilaporkan nilainya ialah 1.29 ha / jam dan 79.5% masing-masing, tetapi apabila kelajuan ditetapkan atau ditingkatkan kepada 0.45 m / s nilai-nilai ini berubah kepada 1.55 ha / jam dan 75%.

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I certify that a Thesis Examination Committee has met on 9 September 2016 to conduct the final examination of Usman Bashar Zubairu on his thesis entitled "Design and Development of Sri Single Seedling Transplanting Implement with Seedlings in Semi-Dried Clay Media" 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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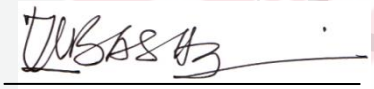
Signature:  Date: _____

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

%	Percent
ha	Hectare
M_{1000}	Mass of 1000 seeds
m^3	Meter cube
MC	Moisture content
M_f	Final moisture content
M_i	Initial moisture content
mm	millimeter
hr	Hour
kg	kilogram
^oC	Degree Celsius
PVC	Polyvinyl chloride
Q	Mass of water added to seed
R^2	Coefficient of determination
cm	centimeter
SRI	System of Rice Intensification
FAO	Food and Agricultural Organization
IRRI	International Rice Research Institute
SSL	Self Sufficiency Level
DAS	Days After Sowing
rpm	Revolution Per Minute
TKL	Tonjong Karang Lot
UNEP	United Nations Environmental Programme
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IWMI	International Water Management Institute
UNDESA	United Nations Department of Economic and Social Affairs
WWAP	World Water Assessment Programme
kmph	kilometer per hour
m/sec	meter per second
m^2	meter square
ha/hrs	hectare per hours
FAOSTAT	Food and Agricultural Organization Statistical data
RM	Ringgit Malaysia
kg/ha	Kilogram per hectare
MR219	Malaysian Rice Variety 219
AWD	Alternate Wetting and Drying
RKB	Rice Knowledge Bank

S/N	Serial Number
w	Width of the coverage
S	Speed of operation
t/ha	Tonnes per hectare
SSTi	Single Seedling Transplanting Implement
Li	Loosening index
ANOVA	Analysis of Variance
RCBD	Random Complete Block Design
SAS	Statistical Analysis Software
DMRT	Duncan Mean Ranging Test
T_H	Turning Head
T_R	Reloading time
W_f	Width of the field
W_p	Width of the planter
acre/hr	Acre per hour
M_1	Clay + compost
M_2	Clay alone
M_3	Clay + loam + compost
M_4	Loam alone
V_m	Volume of media
A	Area
h	Height
S_n	Number of seedling
S_{pt}	Spacing pattern
S_t	Number of seedlings per tray
T_t	Number of trays per planting area
S_1	Speed at 0.18 m/s
S_2	Speed at 0.24 m/s
S_3	Speed at 0.45 m/s
R_1; R_2;R_3	Replications
T_w	Working time
N_a	Nursery area
AFC	Actual Field Capacity
TFC	Theoretical Field Capacity
FE	Field Efficiency
FC	Field Capacity

CHAPTER 1

INTRODUCTION

1.1 Background

Rice (*Oriza Sativa L*.) in Asia or (*Oriza Glaberrima*) in Africa stands as a staple food to most of the world's human population with the highest consumption in the Asian region. It is classified as the third – highest worldwide production after Sugarcane and Maize (FAOSTAT, 2012). Research has indicated that, it is good source of protein and also plays a vital role in nutrition to much more number of world populations with significant figure in Asia, Latin America and Africa (Brown & Funk, 2008; Bruinsma, 2009; FAO, 2012; Godfray et al., 2010). According to FAOSTAT (2012), this versatile crop represents a central food security to over half of the world populations.

Despite all these advantages on rice, the issues of food security and climate change with respect to current population growth are becoming a major concern to the plurality of the researchers in finding ways of converting the unpredicted menace in order to meet the global rice demand. Moreover, the findings of FAO (2014) revealed that the total growing area dedicated to rice worldwide has been estimated as 162.3 million hectares in 2012 with an annual production of 738.1 million tons. Out of this figure over 90% (612 million tons) comes from Asian countries produced on 143 million hectares with China holding the first position and seconded by India having an annual estimate of 157 million tons but still could not meet the world demand and the possibility of increasing or expanding the paddy growing area in the near future is becoming difficult and limited due to urbanization and climate change. Furthermore, World Population Datasheet (2012) indicated that world population is increasing rapidly with higher significance in developing countries than developed ones. Likewise, FAO (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% 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% of the population. Moreover, an estimation of 25% of world food production may likely be at lost by 2050 as result of climate change, water scarcity and land degradation; thereby rendering 10 to 20% of the world's growing population into hunger (UNEP, 2011).

Therefore, having these unwanted challenging situations in minds, the Malaysian Government brought out a program in 2008 tagged "100% Self Sufficiency Level (SSL) in Rice by 2015" with the primary aim of balancing the gap between the production and the population demand. Achieving these challenging objectives can only be possible through the creation of modern techniques for ameliorating the production yield which is proportional to the seedling quality and transplanting pattern. Therefore, these techniques require

improvement on the current seedling transplanting practices to suite the full mechanization SRI transplanting and spacing standards.

The advert of the System of Rice Intensification popularly known as (SRI) was first introduced and /or noticed in Madagascar by a French Researcher Fr. Henri de Laulanié more than 30 years ago, that has now proven to be one of the most recent agricultural innovations that modify certain practices for managing plant, soil, water and nutrients. It is also a system that relooks into most of the researchers' ideology on the yield whose common notion was based on high investments on seeds, irrigation, high doses of fertilizers and pesticides in order to boost rice yield. This new integrated crop management practice can raise not only the productivity of the land, labor, water but also that of capital invested in irrigated rice production (Lalanie', 2003; Uphoff *et al.*, 2010). Consequently, it is a system that aims at improving primarily 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 – 100% or even more thereby saving irrigated water use between 25 – 50% with a credible saving of 80 – 90% of seeds and also relying more on organic matter rather than chemical fertilizers.

In rice production, the quality of the seedling and farmers' transplanting skills (spacing and seedling number per hill) play a paramount objective in promoting optimum yield. Despite some researchers agitation that the yield of rice can only be increased with increase in fertilizer application, but this philosophic ideology is now getting gradual contradicting challenges with the advent of the System of Rice Intensification (SRI) techniques/ innovations by changing the management of the plants, soil, water and nutrients utilized in paddy rice production. Specifically, it involves the transplanting of single but young and delicate seedling with wider spacing, carefully and quickly into fields that are not kept continuously flooded, and whose soil has more organic matter with little or no fertilizer and is actively aerated (Anas et al., 2011; Misha & Uphoff, 2011; Singh, 2012). These practices not only improve the growth and functioning of rice plants root systems but also enhance the number and diversity of the soil biota that contribute to plant health and its productivity (Kassam, Stoop, & Uphoff, 2011; Mishra & Salokhe, 2011; Randriamiharisoa, Barison, & Uphoff, 2006; Stoop et al., 2002). In addition, farmers' and Researchers' reports have verified that SRI crops are more resistant to most pests and diseases, and better able to tolerate adverse climatic influences such as drought, storms, hot spells or cold snaps. The length of the crop cycle (time to maturity) is also reduced, with higher yields.

Therefore, this proposed SRI single seedling transplanting implement for semi-dried clay seedlings is considered to be one of the recent SRI innovations that enhances the placement/planting of exactly one young, delicate but undisturbed root and healthy seedling in the puddled field at varying SRI

spacing standards. Moreover, much emphasis was put on single seedling placing both in the nursery and in the field in order to eventually reduce seedling trauma, transplanting shock and damage as well as to promote increased productivity.

1.2 Statement of the Problems

The requirements of SRI systems are to transplant single seedling at a very young age of about 8 to 10 days after seed germination in a nursery with innovative spacing of 20 x 25cm, 25 x 25cm, 30 x 30cm or 40 x 40cm or even more depending on field topography and soil fertility. Despite all these versatile opportunities on SRI-rice production practices, the current techniques of seedling transplanting still remain a challenging constrain among SRI practitioners as the existing transplanting machines do not accurately respond to the full SRI transplanting conditions of single seedling per hill with respect to SRI spacing patterns geometry. Although, several attempts were made by different researchers on the modification of the existing transplanting machines to satisfy full SRI mechanized farming (Chiu & Fon, 2000; Dhananchezhiyan et al., 2013; Dixit et al., 2007; Ersson et al., 2011; Hussain et al., 2013) among others, but still the problem of multiple planting per hill, noticeable percentage of unplanted hills and non-compliance of SRI spacing standards within and between rows continue to remain as farmers nightmare. Consequently, the only promising practice that accurately tallies with the SRI principles is manual transplanting but it engulfs high labor requirement ranging from 180 to 250 man/hr/ha (Dixit et al., 2007; Farooq et al., 2011; Joshi et al., 2013) and others stresses of long hours of bending with bare feet in the puddled field, transplanting shock as a result of pulling and less profitable as the resources are becoming increasingly scarce among others. Therefore, in order to wipe away these existing stresses of manual transplanting as well as reducing the transplanting shock experienced by the young rice plant and other hindering production costs, the new innovative transplanting implement has been set on board and tagged as “SRI single seedling transplanting implement for semi-dried clay media” to serve as a pathway in addressing issues relating to full compliance of SRI planting and spacing mechanization to enhance its sustainability.

1.3 Purpose and Objectives of the study

The main objective is to mechanize the transplanting of seedling attached to specific soil media and the specific objectives are:

1. To design a transplanting implement with adjustable SRI spacing pattern for an effective planting standard in the field.
2. To fabricate the most suitable SRI transplanting implement for the developed SRI tray to plant one seedling per hill in the field.
3. To recommend the most suitable soil media for seedling to be placed by the transplanting implement.
4. To test the performance of the developed machine in the paddy field at varying SRI spacing patterns.

1.4 Scope and limitation

The scope of this research shall be to design, develop and evaluate SRI transplanting implement capable of placing single seedling per hill with respect to SRI spacing standards using established seedlings from SRI-tray.

The limitation shall only be to study on the single seedling transplanting implement with seedlings in semi-dried clay to transplant one variety of rice and compare the various SRI spacing patterns.

The research is only limited to transplanting and observe the establishment without going up to yield.

1.5 Thesis layout

The thesis was divided into five chapters. Chapter one – Introduction, discusses the background on the transplanting implement, its importance, applications and adaptability. It discusses also on the problem statement and the gap in knowledge from previous works on the transplanting implement, why the fundamental research was important, purpose and objectives and then scope and limitation of the work. Chapter two presents literature reviewed on nursery management, soil-bearing seedling growing media types as well as on other transplanting machines although non SRI compliance in terms of planting performance and SRI single seedling spacing and also on the current status of the mechanized SRI . Chapter three discusses the design and development of the SRI transplanting implement, materials and methods used to conduct the research from implement development, site clearing and planting performance tests with respect to other transplanting machines. Chapter four present results and discussions on experiments conducted from nursery management to design performance and transplanting. Summary, conclusions and recommendations for further works on the SRI single seedling transplanting machine implement are presented in chapter five.

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Zubairu U. B., Wayayok, A., Mohd, A., & Mohd, S. (2014). Determination of some physical properties of common Malaysian rice MR219 seeds. *Australian Journal of Crop Science*, *8*(3), 332–337.

BIODATA OF STUDENT

Usman Bashar Zubairu was born in Birnin Kebbi town on 8th of August, 1968. He attended his primary education at Illelar Yari Primary School, Birnin Kebbi from 1976 to 1980 and proceeded to Government Science Secondary School, Yabo between 1981 and 1986 and obtained his West African Examination Council (WAEC O/LEVEL) certificate. His Bachelor degree was obtained in 1996 from IPDR in the Republic of Niger in the field of Civil / Rural Development Engineering. He also attended other courses such as Postgraduate Diploma in Water Resources and Environmental Engineering (2001 – 2002), Postgraduate Diploma in Education (2004 - 2005) as well as Conferences, Workshops and Seminars. He is currently serving as a Lecturer with Waziri Umaru Federal Polytechnic, Nigeria and also registered member with Nigerian Institution of Agricultural Engineers (NIAE), Nigerian Society of Engineers (MNSE), Teachers Registration Council (MTRC) and Council for the Regulation of Engineering in Nigeria (MCOREN). He was admitted into Universiti Putra Malaysia in September, 2011 for Master of Science in Soil & Water and later in October, 2013 for a Doctor of Philosophy in Soil and Water engineering.

LIST OF PUBLICATIONS

1. **Patent**

Zubairu, U.B, Aimrun W, Amin M.S.M and **Razif M. (**2014). SRI Single Seedling Transpalnting Machine Implement. Patented on 08th May 2013. File No. PI 2013700745

2. **Journal**

Zubairu U.B, Aimrun W and **Amin M.S.M**, (2014). Determination of some physical properties of common Malaysian rice MR219 seeds. Australian Journal of Crop Science. AJCS8(3):332 – 337. (ISI)

Zubairu U.B, Aimrun W, Amin M.S.M and Razif M.M, (2014). Quality Seeds: An Innovative Sorting Technique to Sustainable, Uniform and Effective Seedling Eatablishment in Nursery for System of Rice Intensification. Journal of Agricultural Science. Vol.6(7): 185 – 193.

Zubairu U.B, Aimrun W, Amin M.S.M and Razif M.M. Single Seedling Nursery Tray: An Innovative Breakthrough to Quality Seedling Raising Technique for SRI Transplanting Machine. Research Journal of Applied Sciences, Engineering and Technology. Accepted Manuscript ID: 15173-RJASET-DOI and on publication process. (Elsevier Scopus)

Zubairu U.B, Aimrun W, Amin M.S.M and Ezrin M.H, (2014). Comparison of Precision Farming and Conventional Practices for Paddy Fertilizer Management. Bothalia Journal. Published. (ISI)

Aimrun W, Amin M.S.M, U. Mohammed, A. Khalina and Zubairu U.B. (2015). Influence of Soil Cover on Moisture Content and Weeds Suppression under System of Rice Intensification. Paddy and Water Environ. Published (Springer)

Zubairu U.B, Aimrun W, Amin M.S.M and Razif M.M: *SRI –Tray*: Breakthrough in Nursery Management for the System of Rice Intensification. ***Jurnal Teknologi (Sciences & Engineering) 78:1–2 (2016) 65–71***

Bande Yahaya Muhammad, Adam Nor Mariah, Jamarei Bin Othman, Azmi Yahya and Zubairu Usman Bashar, (2013). Egusi melon (Citrullus Lanatus) crop – Malaysian new oil/energy source: Production, processing and prospects. Australian Journal of Crop Science. AJCS 7(13):2101 – 2107. (ISI)

3. **Conference**

Zubairu, U.B., **Aimrun W.** and **Amin M.S.M**. (2013). SRI Single Seedling Nursery Tray: An Innovative Breakthrough to Challenges in Raising and Transplanting Seedlings. *2nd SRI National Conference (SRI2013). 11 - 13th June 201*3. The Orient Star Resort, Lumut, Perak

Zubairu U.B, Aimrun W, Amin M.S.M and Ezrin M.H, (2014). SRI Single Seedling Nursery Tray: An Alternative to Vigorous Seedling For System of Rice Intensification Planting Machine. 2nd International Conference on Agricultural and Food Engineering (CAFEi 2014). 1-3 December 2014, Berjaya Times Square Hotel, Kuala Lumpur.

Zubairu, U.B., **Aimrun W. Amin M.S.M and M. Umar**. (2015). Comparative study on seedling performance raised by new single seedling nursery tray and conventional system: South-East Asia Regional SRI Conference 2015(SEASRI 2015), 25 – 28 May 2015. TH Hotel, Kedah, Malaysia.

Zubairu U.B, Aimrun W, Amin M.S.M and Razif M.M: *SRI –Tray*: Breakthrough in Nursery Management for the System of Rice Intensification. PAWEES-INWEPF Joint International Conference, Kuala Lumpur, Malaysia, 19 – 21 August 2015

4. **Awards**

Gold Medal Award: Malaysian Innovation Expo 2013 (MIExpo 2013) on 26th -28th September 2013. SRI Single Seedling Nursery Tray for SRI. Authors; Zubairu Usman Bashar, Aimrun Wayayok, Mohd Amin Mohd Soom and Razif Mohammad Mahadi

Bronze Medal Award: Malaysian Association of Research Scientists, Malaysia Technology Expo 2014 (MTE 2014) on 20th – 22nd February 2013. SRI Single Seedling Nursery Tray for SRI Planting Machine. Authors; Zubairu Usman Bashar, Aimrun Wayayok, Mohd Amin Mohd Soom and Razif Mohammad Mahadi

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