UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF PADDY PRECISION PLANTER FOR SYSTEM OF RICE INTENSIFICATION

TUKUR DAIYABU ABDULKADIR

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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

July 2015

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DEDICATION

This thesis is dedicated to my late father and my beloved mother

Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Master of Science

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July 2015

Chairman: Wan Ishak Wan Ismail, PhD
Faculty: Engineering

High labor demand especially at the seedling establishment stage is one of the major challenges faced by paddy farmers in adopting the system of rice intensification (SRI). In this research Gaspardo pneumatic seeder SPS540 was modified and adopted to the direct seeding of coated paddy for the system of rice intensification (SRI), with the aim of solving the drudgery faced by farmers in adopting the SRI. Paddy seeds were fed in to starch and gelatin capsule at the ratio of 1:1 with the capsule serving as paddy coating material to achieve a uniform planting material for single seed planting requirement of the system of rice intensification. Germination analysis for the capsulated seed was conducted in a preliminary study where a germination rate of 92% was achieved with starch capsule coated pre germinated paddy seed. Lower germination rate of 16% was recorded for the case of gelatin capsulated pre germinated paddy. Second round of germination test was conducted using starch capsule, with three treatments of primed coated seed, pre germinated coated seed, and untreated uncoated (control) paddy seed. The highest germination count of 95% was observed with pre germinated coated paddy, followed by primed coated paddy 83%, and the lowest germination count 58% was observed in the control. Solubility of both gelatin and starch capsule in water were compared. Starch capsule was found to have higher solubility at lower temperature corresponding to the paddy environment temperature. The physical, mechanical and aerodynamic properties of the capsulated paddy seed was determined based on which two seed plates designs suitable for capsulated paddy planting were designed and fabricated. One of the designs has 0^o entry angle, while the second has 120^o entry angle. An electro mechanical seed spacing and metering system was developed from a metering wheel, encoder, servo motor, and arduino micro controller to replace the existing mechanical seed spacing and metering system for improved machine performance. The limit switch (encoder) and the servo motor were programmed using Arduino microcontroller for seed metering. At each designated distance the limit switch will actuate the servo motor to rotate and drop a single seed. The machine was calibrated at the laboratory and performance evaluation of the machine conducted there based on average seed spacing, miss index, multiple index, and quality of feed index. The best performance indices of 25.4 cm average seed spacing, 0% miss index, 0% multiple index, and 100% quality of feed index was observed

with zero entry angle seed plate at operational parameters of 10 mbar and 1 m/s. The machine was then evaluated in the field using same performance indices as in the laboratory evaluation. At the field, comparison between the conventional (mechanical) seed metering system and the developed electronic system was made using T test. The T test result proved electronic seed metering system with 32.90 cm seed spacing, 96.30% quality of feed index, 3.7% miss index, and 0% multiple index to be better than the mechanical seed metering system with 21.53 cm average seed spacing, 76.19% quality of feed index, 7.22% miss index, and 16.59% multiple index.

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

PEMBANGUNAN JENTERA PENANAM PADI KEPERSISAN UNTUK SISTEM PENINGKATAN KEGIGIHAN BERAS

Oleh

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Dalam kajian ini, penyemai benih pneumatik Gaspardo SPS540 telah diubahsuai dan diguna pakai bagi proses pembenihan langsung padi bersalut untuk sistem intensifikasi padi (SRI). Benih padi dimasukkan ke dalam kanji kapsul dan gelatin pada nisbah 1:1, kapsul berfungsi sebagai bahan salutan padi untuk mencapai keseragaman terhadap benih tunggal bagi keperluan sistem intensifikasi padi. Hasil kajian yang dilakukan memperlihatkan kadar percambahan benih yang berkapsul sebanyak 92% telah dicapai dengan padi yang bersalut kanji pra cambah, kadar percambahan yang paling rendah yang dicatat bagi kes padi bersalut gelatin yang berkapsul pra cambah adalah sebanyak 16%. Analisis kedua, percambahan telah dijalankan berdasarkan blok rawak lengkap (CRD) dengan tiga replikasi menggunakan kapsul kanji sebagai bahan salutan. Tiga rawatan adalah terdiri daripada padi yang bersalut sepenuhnya, pra bercambah bersalut, dan padi yang tidak dirawat (kawalan) telah digunakan untuk ujian percambahan. Hasil percambahan tertinggi adalah sebanyak 95% yang diperolehi melalui rawatan pra bercambah padi bersalut. Kemudian, diikuti dengan rawatan padi bersalut sepenuhnya iaitu sebanyak 83%. Kadar kiraan yang paling rendah adalah sebanyak 58% bagi rawatan padi yang tidak dirawat (kawalan).

Kadar larut bagi kapsul gelatin dan kanji di dalam air telah dibandingkan. Hal ini menunjukkan bahawa kapsul kanji didapati mempunyai kadar larut yang lebih tinggi di bawah kondisi yang dipertimbangkan.

Dalam fasa kedua kajian ini, sifat-sifat fizikal, mekanikal dan aerodinamik benih padi yang berkapsul telah ditentukan berdasarkan reka bentuk dua plat benih. Berdasarkan kajian ini, plat yang sesuai untuk penanaman padi berkapsul telah dicipta. Salah satu reka bentuk yang telah dicipta mempunyai sudut kemasukan sifar darjah , manakala yang kedua pula mempunyai sudut 120^{o} untuk sudut kemasukan. Dalam kajian fasa ketiga, sistem penjarakkan benih kawalan elektro mekanikal telah digunakan. Sebuah elektro mekanikal sistem penjarakkan benih telah direka dan dibangunkan untuk menggantikan sistem penjarakkan mekanikal yang sedia ada bertujuan meningkatkan prestasi mesin. Satu roda yang bermeter telah direka dan dibina untuk mengukur jarak benih, manakala sistem penghantaran rangkaian kuasa

dan rantaian dalam sistem konvensional telah digantikan dengan satu set motor servo untuk setiap (plat). Satu suis pengehad dan motor servo yang telah diprogramkan dengan menggunakan *Arduino* sebagai pengawal mikro. Pada jarak yang ditetapkan, setiap suis penghad akan menggerakkan motor servo untuk memutar dan menggugurkan benih tunggal. Mesin ini telah dikolaborasikan mengikut penilaian makmal dan prestasi mesin yang diujikaji berdasarkan purata jarak benih, indeks tidak mengena, indeks pelbagai dan indeks kualiti masukkan. Indeks prestasi terbaik adalah 25.4cm bagi purata jarak benih, 0% untuk indeks tidak mengena, 0% untuk indeks pelbagai, dan 100% kualiti indeks kemasukan. Kadar ini dinilai pada sudut kemasukan sifar darjah plat benih pada parameter operasi 10mbar dan 1 m/s. Mesin ini kemudiannya diuji di kawasan lapang dengan menggunakan parameter yang sama iaitu purata jarak benih, indeks tidak mengena, indeks pelbagai, dan kualiti indeks kemasukan. Di ladang, perbandingan antara sistem pemeteran (mekanikal) benih konvensional dengan sistem elektronik yang dibangunkan serta dinilai dengan menggunakan ANOVA dan ujian T. Hasil ujian T membuktikan bahawa sistem pemeteran benih elektronik lebih baik daripada sistem benih pemeteran mekanikal.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
AV	Average seed spacing
C	Circumference
$CaCl_2$	Calcium Chloride
COM	Communication
CU	Coefficient of uniformity
CV	Coefficient of variation
D	Diameter
DC	Direct current
EEPROM	Electrically erasable programmable read only memory
KB	Kilo byte
KCl_2	Potassium chloride
KNO_3	Potassium trioxo nitrate five
L	Length
LCD	Liquid crystal display
MI	Miss index
MTI	Multiple index
NO	Normally open
PTO	Power take off
PVC	Polyvinyl chloride
PWM	Pulse width modulation
QFI	Quality of feed index
RC	Radio controlled
RGB	Red green blue
SRAM	Static random access memory
SRI	System of rice intensification
SV	significance value
T	Thickness
W	Width

CHAPTER 1

INTRODUCTION

1.1 Background

Rice is the world's most staple and vital food crop and the main food source for more than half of the world's population. About 80% of rice global harvest is cultivated in Asia, with about 33% coming from Southeast Asia alone. Rice is planted on about 154 million hectares annually which accounts for about 11% of the world's cultivated land (Redfern, Azzu, & Binamira, 2012). Rice cultivation is one of the most important economic activities on the earth.

The world population is growing exponentially while more paddy land is being converted to residential buildings or used for other industrial and commercial purposes. Water that is supposed to be used for irrigation purposes is being diverted to other economic, residential and industrial uses. These challenges pose the need for a more productive cultivation practice with higher yields and less water demand.

In the late 1980s, a system of rice cultivation called system of rice intensification (SRI) was developed in Madagascar. Many researchers have proven SRI to give high yield per unit area (9.9 t/ha) as reported by (Tsujimoto, Horie, Randriamihary, Shiraiwa, & Homma, 2009). SRI is a rice cultivation system that involves good water management practice, use of organic fertilizer, and zero chemical herbicide that result in higher yield. SRI is dynamic and environment dependent, meaning that the system is not fixed but can be adjusted to adapt to different environments. Whereas paddy field is flooded in the conventional paddy cultivation system, this is not the case with SRI. Water is only applied to the paddy at the right proportion base on demand. One of the basic requirements in SRI is the planting of single paddy seed per stand which is quite tedious due the irregular paddy shape and its minute size.

Mechanization of seed establishment method was achieved by means of mechanical seeders. The first mechanical seeder was invented by Jethro Tull (1674-1741). Prior to this invention, all seed planting operations were done manually. Jethro seeder was able to dig a hole, drop a seed and cover it (Johnson, 1844).

A mechanical seed planter is a machine that cut the soil, drop a seed and cover the soil with or without a constant inter and intra raw spacing. Mechanical planter is classified in to the following major classes: seed broadcaster, mechanical seed drill, precision planter, Hand Dibbler, and specialize planters. Seed broadcaster as the name implies utilizes blower or other mechanical means to broadcast the seed on the farmland. A mechanical seed drill is a machine that cuts the soil drop the seed and cover the soil with a constant inter raw spacing, but without intra raw spacing. A precision planter is a machine that cut the soil drop the seed and cover the soil with a constant inter raw and intra raw spacing.

One of the most effective seed singulation methods is by the use of vacuum planter (Murray, Tullberg, & Basnet, 2006a). Vacuum planter is a type of mechanical

planter, it is in other word called a precision seeder. Is a machine that cut the soil drop a single seed and cover the soil with a constant inter and intra raw spacing using a pneumatic fan for the purpose of picking single seed. In general, a vacuum planter consists of vacuum fan powered by tractor PTO, a seed hopper, a metering housing containing a seed plate. During operation a seed plate rotates inside the plate housing and pick a single seed flowing down a hopper via a seed cell designed to be less in diameter than the seed to be planted, the seed is held to the seed cell due to negative suction provided by the vacuum fan, the plate rotates to the bottom of the housing that is exposed to the external pressure and the seed is dropped, the plate consist of many seed cells aligned along a circumference depending on the design and purpose of the planter (Murray,Tullberg, & Basnet, 2006a).

Despite the ability and potentials attached to vacuum planter to singulate different seeds, yet paddy singulation cannot be achieved with vacuum planter in the conventional method. Hence the need to modify it for SRI seed establishment process.

Gaspardo vacuum planter is a brand of vacuum planter designed for multipurpose seed planting. Basically, it consist of a metallic beam to which all other components are connected either directly or indirectly via other attachments, a vacuum fan in between the three point hitch that is powered by tractor power takeoff (PTO). The vacuum generated is channeled through vacuum horse to the metering unit, mounted on the beam. The metering unit consists of plastic hopper where seeds are poured and covered for protection against foreign materials, dust, and moisture in the event of rainfall. At the bottom of the plastic hopper is the steel seed metering housing. It consists of a vertical housing with rubber seals to make the housing air tight. Seed plate is also mounted inside the housing. The housing is partitioned into two parts that could be opened if the need for changing seed plate arises with the seed plate at the center. At one side is a cylindrical protruded pipe to which the vacuum horse is attached. The seeds flow in to the housing via the other side of the housing opposite the vacuum horse part. The seed plate is circular plate equipped with seed cells for seed picking and tabs that help to scoop seeds to the seed cells.

Seed coating is a practice usually done to protect planting materials from damages by agents such as insects, rodents, and germs. It could also be made for the purpose of enhancing the planting material with a particular nutrient that is deficit in the soil. Seed coating is achieved by mixing a small amount of the active ingredient to a large amount of inactive ingredient called carrier and then rubbed at the back of the seeds. For the purpose of this study, Seed coating becomes the main option to achieve paddy singulation via seed capsulation.

A basic requirement of SRI is the placement of single seed per stand at a constant distance, this distance depend on the soil fertility but usually ranges between 25-30 cm, where the soil fertility is high the spacing should be more and vice versa. Another requirement of SRI is mechanical weeding at several stages of development in order to destroy the weeds for the purpose of reducing competition for nutrients and also to aerate the soil for good root growth and higher tiller establishment.
Over the years, many mechanical drives in industries, agricultural machineries, as well as automobile are being replaced with electronic drive with the aim of achieving

a better control and precise movement, which is the current trend of technological development. One of the objectives of this research is to develop an electronic system for seed spacing measurement system of a pneumatic seeding machine for increased machine performance. Going by the history, agriculture was initially powered and controlled by manual labor, at early Stage of human advancement, animal and mechanical labor came in. Today we are at an advance stage of precision agriculture with the aid of automation gadgets. These automation gadgets include sensing, data acquisition, processing, actuation and monitoring devices.

Servo motor was defined as the heart of many mechatronics applications and its successful application depends on objective selection procedure subject to capacity to provide the required torque at the designated speed followed by economic, volume, weight, type of material and other relevant parameters.

1.2 Rice production in Malaysia

Paddy cultivation in Malaysia was initially attributed to the rural dwellers and practiced as a traditional system. Malaysian government have initiated so many policies to aid rice producers, these include declaring paddy as a security crop, initiating fertilizer subsidy scheme, upgrading the existing irrigation schemes and development of new schemes, initiating and establishing the agricultural act (1992-2010), the establishment of marketing board and price control scheme. Malaysian rice producers were able to meet up to 76% of the country's rice demand, while the remaining 24% is balanced through import from neighboring countries such as Thailand, Cambodia, India and Indonesia (Toriman, et al., 2014).. The farmer's goal is increasing production and productivity via the introduction of high yielding cultivars, intensification of the cultivation practice such as the use of herbicide, fertilizer cycle, and reviewing the conventional use of fertilizers and other vital inputs.

After independence the Malaysian government increases the acreage for rice for two basic reasons. One the Malaysian government considered rice as security crop because a Malaysian family finds it difficult to survive without taking rice two to three times daily, in fact rice is the most popular food in Malaysian culture. The second reason being the major employment provider in the agricultural sector, as of 1983 it provides about 80% of all the employment generated from the agricultural sector even though 54% rice farmers of that era were found to be living below the national poverty level due to the low income generated from rice farming.

To address this challenge the government initiated some policies to aid rice farmers and increase their income. These policies involves development of more irrigation lands to enable rice farmers achieve two seasons of rice cultivation annually, development of better planting materials through government funded research varsities, and other institutions for the purpose of achieving high yield, provision of high quality fertilizer and pesticides at a highly subsidized rate, and usually on loan, provision of machineries to supplement the labor shortages and reduce the cost, establishment of marketing bodies to stabilizes price and monopolize the market for local production, soft loan accessibility to farmers via the agricultural banks at

subsidize or zero interest, the farmers were organized through institutional organizations in to districts for easier access to government and other research agencies (Teik, 1985).

1.3 Statement of the problem

Increasing cost of labor, high cost of machinery and irrigation water scarcity are among the factors posing a serious threat to sustainable rice cultivation in general. In spite the many advantages attributed to SRI farmers find it difficult to adopt due to its high labor demand. SRI is based upon practices that involves, precise placement of single seeds with a fixed spacing between seeds, and mechanical weeding at several stages of growth. Vacuum seeder is on the efficient ways of precision seeding. Due to the irregular shape of paddy the seed the metering device of conventional vacuum seeder cannot maintain delivering single seed of paddy at regular intervals, it rather result in multiple seeding, in most cases the seeds end up blocking the seed holes, or high rate of skips when the seed cell is too small. Rice seeders such as the drum seeder were developed to be used for SRI seed establishment practice. This was found to be in efficient in terms of seed singulation and spacing, and there used to be incidences of doubles and skips which affect the two ways mechanical weeding required in SRI.

Coating paddy seed with capsules can help to addressed seed singulation. Due to the low density of capsulated paddy, seeds dropping from a pneumatic seeder using the conventional seed plate are sucked back by a neighboring seed cell under the effect of vacuum. A seed plate with 8 seed cells, widely spaced was developed to address the above problem. The existing Pneumatic seeders were developed for seeds plate with 16 and above seed holes. There is no spacing combination to achieve 25 cm seed spacing with 8 holes seed plate from the conventional pneumatic seeder. To address the above challenges the need arise for the modification of the existing pneumatic seeder's metering and spacing system to suit SRI practice.

This research is aimed at modification of a mechanical planter to suit the adoption of System of Rice Intensification (SRI) for paddy planting.

1.4 Objectives of the research

1. The determination of suitability of pharmaceutical capsule as a paddy coating material.
2. Determination of the physical, mechanical, and aerodynamic properties of coated paddy.
3. Development of an electromechanical seed spacing and metering system for vacuum seeder.
4. Performance evaluation of the developed seeder both in the laboratory and at the field.

1.5 Scope of the Research

The scope of this research is to modify Gaspardo SP540 vacuum seed planter for SRI seed establishment process using a capsulated paddy seed as a planting material.

1.6 Thesis Organization

The thesis presented consists of five chapters: introduction, problem statement, objectives of the study, and scope of research are presented in chapter 1. Chapter two contains review of some of the available relevant information. The methodology of conducting the research is presented in chapter three. The results of the evaluations and other measurements conducted in the course of this research were presented and discussed in chapter four. Recommendations and conclusion were presented in chapter five.

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