UNIVERSITI PUTRA MALAYSIA

DESIGN, DEVELOPEMENT AND EVALUATION OF A KENAF PNEUMATIC SEEDING MACHINE

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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 Doctor of Philosophy

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DEDICATION

This thesis is specially dedicated to my beloved family; my dear mother and father, my wife and son, and my sisters and brothers

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

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By

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Chairman: Desa Bin Ahmad, PhD, P. Eng

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In this study a 4-row, tractor mounted, kenaf pneumatic seeding machine was designed and developed based on physical, mechanical and aerodynamic properties of kenaf seed (*Hibiscus cannabinus* L.). The machine is made up of: (a) a chassis which is supported to move across and over fields by at least one drive wheel and one driven wheel (two transportable wheels); (b) four units of planters each consisting of a vacuum seed metering system; furrow opener (furrower); seed opener; seed cover; press wheel; and seed hopper. The vacuum seed metering system (each unit planter has one vacuum seed metering system) includes a seed container, a seed plate having a plurality of circular array openings and tabs, and a cover. The seed container has an adjustable upper cutoff brush and lower cutoff brush to dislodge any extra or double seeds picked up by the seed plate; and a first and second separators; (c) a pulley and vacuum fan to provide negative pressure for vacuum seed metering system; (d) a transmission power system holding a gearbox; chains and sprockets; and pinions and crown wheels to transfer power from drive wheel to the rotating seed plate of the vacuum seed metering system.

The pneumatic seeding machine was evaluated both in the laboratory and field using kenaf seeds. For laboratory test, a completely randomized design (CRD) with three replications and for field tests a randomized complete block design (RCBD) with three replications were chosen. The data were analyzed by SAS program version 9.1 and means separation test were done using Duncan's multiple range test (DMRT). Regression analysis was used to determine the relationship between appropriate pairs of dependent and independent variables. Based on this study, the most suitable opening diameter and opening angle for planting kenaf seed are 3.5 mm and 120^o respectively. The results obtained also showed that the most suitable vacuum pressure to pick up and keeping kenaf seed to plant in the soil was more than 3 kPa and the most suitable linear speed belonged to speed range of less than 1.5 km/hr.

The average field efficiency of the 4-row pneumatic seeding machine was found to be 74%. The theoretical field capacities for different forward speeds of 2.05, 2.66, 3.63, 3.89 and 5.50 km/hr were 2.30, 2.98, 4.07, 4.36 and 6.16 ha/day. Based on these data the economical cost of the developed pneumatic seeding machine was analyzed. The total fixed (ownership) cost was obtained as RM4950/year; while the total variable (operating) cost was found to be RM55.26/hour. Therefore total cost calculated for the

machine was RM22189.44/year. Based on this study, if there are 1500 hectares of kenaf plantation area involving 270 growers in Malaysia, for planting kenaf seed twice a year (each time 39 days) and on time, about 35, 24 and 18 of the pneumatic seeding machines are needed for 4-row, 6-row and 8-row planting systems, respectively.

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

REKABENTUK, PEMBANGUNAN DAN PENILAIAN MESIN PENANAM KENAF SECARA PNEUMATIK

Oleh

Mohammad Reza Bakhtiari

Februari 2012

Pengerusi: Desa Bin Ahmad, PhD, P. Eng

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Kajian ini adalah mengenai rekabentuk dan pembinaan sebuah mesin penanam kenaf 4-baris berkuasa pneumatik berasaskan kepada ciri-ciri fizikal, mekanikal dan aerodinamik biji benih Kenaf (*Hibiscus cannabis* L.) Mesin tersebut mempunyai komponen seperti a) chasis untuk bergerak atas permukaan ladang dengan bantuan dua roda dan salah satu roda bertindak sebagai pemacu, b) empat unit penanam dimana setiap unit mempunyai sistem permeteran vakum bijibenih, pembuka alur, saluran bijibenih, roda pemampat dan tangki bijibenih. Sistem permeteran vakum bijibenih mengandungi takungan bijibenih dan piring beserta beberapa lubang berbentuk bulat serta penutup. Takungan bijibenih mempunyai berus bolehlaras untuk mengasingkan lebihan bijibenih yang diangkut oleh piring bijibenih dan dua pengasing., c) talisawat dan kipas vakum untuk mengujudkan

tekanan negatif bagi sistem pemeteran bijibenih dan d) sistem penghantaran kuasa yang mengandungi kotakgiar, rantai dan sprocket, pinan dan roda mahkota untuk mengagihkan kuasa dari roda pemacu ke sistem pemeteran bijibenih dan piring pengagih.

Mesin penanam kenaf secara pneumatik tersebut telah diuji di makmal dan di ladang. Bagi ujian di makmal, ujian rekabentuk secara rawak dengan tiga replikasi telah dilakukan manakala untuk ujian di ladang, ujian Blok Rawak telah dilaksakan dengan tiga replikasi. Data telah dianalisis menggunakan program SAS Versi 9.1 dan ujian perbezaan min dilakukan menggunakan Ujian Duncan (DMRT). Analisis regresi dilakukan untuk mengukur hubungkait antara pelbagai pembolehubah. Berdasarkan kajian ini garispusat lubang dan sudut bukaan lubang yang paling sesuai bagi penanam bijibenih kenaf secara pneumatic adalah 3.5 mm dan 120 darjah. Kajian pengaruh vakum menunjukkan bahawa tekanan yang paling sesuai adalah 3.0 kPa manakala kelajuan lelurus yang paling sesuai adalah dibawah 1.5 km/jam.

Purata kecekapan ladang bagi mesin penanam kenaf empat baris secara pneumatik adalah 74%. Keupayaan ladang teori pada kelajuan 2.05, 2.66, 3.63, 3.89 dan 5.50 km/jam adalah masing-masing 2.30, 2.98, 4.07, 4.36 dan 6.16 ha/hari. Keupayaan ladang berkesan pada kelajuan 2.05, 2.66, 3.63, 3.89 dan 5.50 km/jam adalah masing-masing 1.70, 2.20, 2.97, 3.27 dan 4.64 ha/hari. Berdasarkan kepada data ini analisis kos mesin penanam kenaf pneumatik menunjukkan bahawa kos tetap yang mengandungi susutnilai (RM2700/tahun), faedah dan cukai (RM1650/tahun), perlindungan dan insuran (RM600/tahun) adalah RM4950/tahun manakala kos berubah yang terdiri daripada pembaikan dan penyenggaraan (RM2.67/jam), bahanapi (RM6.05/jam), pelincir (RM0.907/jam), upah buruh (RM5/jam), pemandu traktor (RM5.63/jam) dan sewa traktor (RM35/jam) adalah RM55.26/jam. Untuk tempoh setahun anggaran jumlah kos adalah RM22189.44. Berdasarkan kajian ini, jika terdapat 1500 hektar kawasan kenaf yang melibatkan 270 penanam di Malaysia yang menanam 2 kali setahun selama 39 hari setiap musim penanaman, jumlah mesin yang diperlukan adalah 35 unit bagi mesin penanam 4-baris, 24 unit bagi mesin penanam 6-baris dan 18 unit bagi mesin penanam 8-baris.

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LIST OF ABBREVIATIONS

ANOVA	ANalysis Of VAriance
DMRT	Duncan's Multiple Range Test
CRD	Completely Randomized Design
RCBD	Randomized Complete Block Design
LSD	Least Significant Difference test
ns	Not Significant
SD	Standard Deviation
df	Degree of Freedom
CV	Coefficient of Variation
SAS	Statistical Analysis System
d.b.	Dry Basis (seeds moisture content)
w.b.	Wet Basis (seeds moisture content)
LKTN	Lemago Kenaf dan Tembakau Negara (LKTN: National Kenaf and Tobacco Board)
TPU	Taman Pertanian Universiti (TPU: University Agricultural Park)

CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture is the most important resource for producing food in the world. The increasing world population has posed a great challenge to the food production sector. There are many factors that affect the increase of crop yield, such as improved seed variety, environment and tool conditions, but if all these factors are at an optimum, then increasing production will only be possible with an increase in planting area. However, the available planting areas are limited in the world. Therefore, it is important to find alternative methods of increasing crop yields per unit area. Nevertheless, there are many available methods for increasing crop yields per hectare. These include choosing high yielding crop varieties, good crop establishment, suitable and timely irrigation, appropriate weed control, and favourable growth conditions on suitable soils.

For good crop husbandry seeds must be planted at a suitable depth, with appropriate row spacing, spacing between seeds within rows, and seed density. It is only when these conditions are combined together that better yields can be achieved. Thus, suitable seed planting methods are important for increasing crop yields per hectare.

Seed broadcasting (by hand or machine) is not a suitable method; it has many disadvantages such as, delay planting, labour intensive, irregular planting, problems in protective and harvesting stages. Therefore, in order to mechanize agricultural operations, it is recommended that seeds be planted by machine (grain drill or row crop planter). After the global revolution in the agricultural field occurred, the initial functioning of farming that became mechanized was that of the agricultural crops being planted or seeded (John-Deere, 1981).

Seed planting equipments are generally divided into four types; row-crop planters, grain drills, seed broadcasters, and specialized planters. Row-crop planters are designed to put the seeds in a row form in which the seeds are at a distance from each other which lets the handling of weeds easier by cultivation as well as harvesting becomes more systematic. On the other words, row-crop planting is the name given to the crops that are planted away from one another that allows machines like harvesters and cultivators to function properly. To plant crops such as the corn, cotton, soybeans and sugar beet the use of row-crop planters are adopted, as these crops are required to be placed in rows which will help in the managing of the weeds and proper harvesting. Solid planting is when there is very less space in between the rows just to let the cultivation and other functioning which is cultural to take place. The use of grain drills or seed broadcasters may be adopted to do solid planting. The equipment that gives much exact distribution of seeds along with the depth of seeding to be in an even manner is the grain drills. The seeds are covered in seed broadcasters as it does not contain any furrow opener that is open. For plantation of grain crops like wheat, barley, rice, oats, grain sorghum and rye along with bromegrass such as grassed and legumes, timothy, clover, beans, fescue, alfalfa, peas and soybeans usually solid planting is used. Planters such as the potato planters, transplanters and vegetable planters are used for those crops that need more specialized and unique operations (John-Deere, 1981; Jacobs & Harrell, 1983). Plantation of seeds in uniformity in rows or on the beds that is on a plain land, or crinkled land (planting on flat land, on beds or in furrows) is the aim of many planters and grain drills, these however does not include broadcast planters. Various critical tasks must be executed by these planters to achieve their aim, these tasks include; open a furrow in the soil, meter the seed, place the seed in the soil, cover the seed, and firm the seedbed (Karpenko & Zelenev, 1968; John-Deere, 1981; Jacobs & Harrell, 1983).

Five tasks are performed by these equipments, such as (1) for seeds to properly sprout, the placement of the seeds must be beneath the soil's surface this function is known as the furrow opener which is also called the furrower function, hence, to successfully accomplish this task, a mechanism to open the soil must be given by the planting equipment. The runners or shoes, shovel, double disk, lister openers are the most known kinds of furrow openers, openers of disk and the running of combination. A proper place is made in the soil by the furrower where the seed is kept in the right place. Difference in the conditions of soil, the furrow must manage and sustain the depth of where the seed is placed. Due to the conditions in the environment, the seeds may not get developed properly if they are placed to deep or to high. (2) The rating of the seed is managed by the seed metering system, to get the maximum output from the crops that have been planted, the rate of seeds per hectare (seeds per acre), or kilograms per hectare (pounds per acre) are used. For any machine used for plantation of seeding, the main task that it performs is that of seed metering. A single seed is metered and is then kept in the soil at one time by few systems of seed metering, however, placing more than a single seed at a particular time may be the habit of some planters. Random devices, finger pickup and air devices including both pressure and vacuum are the categories of system of metering seeds for planters of row-crop. Fluted kind of feed cup, picker wheel, opening adjustable, cut-off place being adjustable and system of air are few of other devices for metering. (3) How the crop is developed greatly depends on the placement of the seeds and the distance between them, this can be measured by the seed placement device. There is a connection between the numbers of crops that have developed hence; the placement of the seeds becomes vital for its yield. Even when the conditions are stable, there are high chances of more crops to yield if only the seedbed is properly made and the placement of seed is done in the right manner. When the condition of soil is not even, the placement of seeds must be done in uniformity by the planters. The unit of grain drill seeding has furrower which is fully able to deal with the uncertainties and to put the seeds where ever it is needed. Drop of gravity and the device of drop of power are the two kinds of machines that place the seeds in to the right opening of the furrow. The individual seeds can be placed through drilling or through hill dropping in a team by gravity drop as well as the system of power drop. To ensure there is required space among the seeds or hills, is the main task of the machine of seed placement which will take the seed from the device of metering and will then send it to the furrower. (4) To ensure the seeds that are planted are covered properly is another important task of the seed covering device. By adopting the shovel, paddle, chain covers or disk the seeds can be successfully covered. The covering of seeds can also be done by the planters few of the press wheels. If seeds are spread (broadcasted) in various directions and covering it is important than using other seed covering means must be adopted. The following are the seed covering ways that can be adopted to cover the seeds; cultipacker, drag bars, spike-tooth harrow and covering shovels. (5) Making the seedbed even; press wheel is present for today's seed planters to even out the seedbed and cover soil in which the seed is planted. The quality of the crop increases if the seedbed is firm as it gives the seed planted good moisture in soil. The use of a steel press wheel band or steel press wheel may be adopted if much tighter seedbed is required. The role of a metering machines driving unit may be played by the seed packer wheel, wheel that firms seeds or the press wheel (John-Deere, 1981; Jacobs & Harrell, 1983).

1.2 Statement of the Problem

Kenaf is an important and economical crop in Malaysia. Ahmad (2010), Director General of LKTN, reported in his study that kenaf has been decided to be planted as "New Sources of Growth" by the government of Malaysia, and after palm oil and rubber this will become the third main economic item in the country. By the year 2010, the area for the plantation of kenaf increased to 1500 ha from 42.2 ha in the year 2005, this is about 36 times more area for plantation in 270 estates. Based on the future forecast done by the LKTN, by the year 2011 this area will increase to 3000 ha in 400 estates. However, for plantation of kenaf seed an appropriate seeding machine does not exists.

So far, many planters (seeding machines) have been designed and fabricated, but the existing seeding machines are only suitable for seeds that have almost regular shape or crops with row plantings of more than 50 cm such as corn and sugar beet. Kenaf seeds are irregular in shape, and looks somewhat like a shark's teeth, fairly triangular in shape and sometimes looks like a kidney, with roughly pointed corners (Anonymous, 2012).

Besides the irregular shape and size of kenaf seeds, it has a high angle of internal friction and is most suitable for row plantings of 30-40 cm. The physical, mechanical and aerodynamic properties of kenaf seed are completely different from that of corn and sugarbeet. Therefore, existing seeding machines with high numbers of missing and multiple planting characteristics are not suitable for planting kenaf seeds. Thus, there is a need to design a new planter (seeding machine) based on physical, mechanical and aerodynamic properties of kenaf seed.

Generally, there are two common types of row-crop planters (precision seeders or seeding machines): mechanical planters (mechanical seeding machines) and pneumatic planters (pneumatic seeding machines). In pneumatic seeding machines, the air system (pressure or vacuum) are used to meter seeds. Pneumatic seeding machines consist of seed (metering) plate with metering openings on a predetermined radius. The seeds are collected from the hopper by the meter openings through the application of the pneumatic when the rotation is done in the seed plate. The backing plate consists of a race machine through which the pneumatic vacuum pressure is put on the opening of the meter. The quality of work improves, the rates of seeds are more accurate with less default, the handling and variations of upkeep and seed drift are better, and its implementation has a wide spectrum. These are the few benefits which the precision pneumatic seeders have over mechanical seeders (Özmerzi, et al., 2002; Karayel, et al., 2004).

1.3 Objectives of the Study

The main purpose of this study was to design, develop and evaluate a pneumatic seeding machine for kenaf seeds. The following specific objectives would help to achieve the above main objective:

1. To determine physical, mechanical and aerodynamic properties of kenaf seeds at different moisture contents.
2. To design and develop a vacuum seed metering system and a pneumatic seeding machine based on physical, mechanical and aerodynamic peoperties of kenaf seed.
3. To evaluate the vacuum seed metering system in the laboratory and the pneumatic seeding machine in the field for planting kenaf seeds.
4. To develop relationship between machine factors and the machine performance indices of the developed pneumatic seeding machine.
5. To determine the field efficiency, and theoretical and effective field capacity of the developed pneumatic seeding machine.
6. To determine the economic analysis of the kenaf pneumatic seeding machine.

1.4 Scope of the Research

The scope of the research was to develop a machine which can be used on a flat field with good soil pulverization and enable appropriate weed control. The operational speed for this machine should be less than 3 km/hr.

1.5 Thesis Organization

The thesis presented in five chapters. Chapter One discusses the introductory aspect of the study and contains the problem statement, main objective, specific objectives and the limitation of the study. Literature review is presented in Chapter Two, which overviews relevant information about the study. The methods and materials used are discussed in Chapter Three. Chapter Four discusses the results and findings of the study. Chapter Five presents the conclusion and recommendation for future work. The thesis ends with the reference section.

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