UNIVERSITI PUTRA MALAYSIA

INFLUENCE OF SEEDLING ESTABLISHMENT TECHNIQUES AND IRRIGATION SYSTEMS ON GROWTH, WATER USE EFFICIENCY AND NUTRIENT CONTENT OF RUBBER (Hevea brasiliensis MUELL.ARG)

ABBA NABAYI

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By

ABBA NABAYI

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

April 2016

DEDICATION

TO MY BELOVED PARENTS, FRIENDS AND FAMILY

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

INFLUENCE OF SEEDLING ESTABLISHMENT TECHNIQUES AND IRRIGATION SYSTEMS ON GROWTH, WATER USE EFFICIENCY AND NUTRIENT CONTENT OF RUBBER (*Hevea brasiliensis* MUELL.ARG)

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Chairman : Christopher Teh Boon Sung, PhD
Faculty : Agriculture

Rubber (*Hevea brasiliensis*) is an important crop in tropical Asian countries. In Malaysia, rubber contributes much to the economy of the country through latex production. Latex production requires seedlings that are disease-free, mature quickly and have high field survival rates. However, seedlings production in nursery is associated with the cost of irrigation water and labour. Seedlings that are less vigorous tend to spend a longer time in the field before they become established. BX-1 system (RB 900 tube and BX-1 growing media) is a new nursery planting system introduced by Humibox Sdn. Bhd. with the purpose of replacing the conventional (polybag with soil) way of raising seedlings. A research was conducted in a rain shelter at Field No. 15, Faculty of Agriculture, Universiti Putra Malaysia. The treatments were: BX-1 system with sprinkler (T1), BX-1 system with drip (2), BX-1 system with capillary wick (T3) and soil-polybag with capillary wick (T4), as control. The treatments were laid in RCB design with 3 replications each and data were collected monthly for 8 months. The first objective of the research was to determine the influence of different irrigation systems on rubber seedling growth and leaf nutrient contents (N, P, K, Ca, and Mg). The results showed that the different irrigation systems had influenced the growth and leaves nutrient content significantly ($P<0.01$) with the higher values in the drip (T2) and capillary wick (T3) systems, and the lower values in the sprinkler system and control (soil-polybag). This was due to the higher nutrient content of the BX-1 media which is 4 times more than that in the soil. The use of BX-1 growing media would reduce mineral fertilizer application. The second objective of the research aimed at uncovering the influence of different irrigation systems in nutrient leaching loss (N, P, K, Ca, and Mg), water productivity and water use efficiency of rubber seedlings. The results indicated that the sprinkler system (T1) lost the highest amount of nutrients especially for the more mobile nutrients (such as N and K), while the control (T4) had lost the least nutrients. The lower amount of the nutrients lost in the control was due to the lower nutrient contents in the soil. Higher water productivity was recorded in drip and capillary wick irrigation systems, which differed significantly with sprinkler and control, but in terms of water use efficiency, the highest was recorded in the T4 (control) which was due to the least amount of leachate recorded in the system because of the lower hydraulic conductivity of the soil as compared with the BX-1 growing media. The third objective was to determine the cost benefit analysis between the two different growing systems (BX-1 system and soil-polybag system) of raising rubber nursery seedlings in a 100m^2 area. The analysis revealed that the soil-polybag system had a total expenditure and cost-benefit saving of 92.5 and 32% respectively, over the BX-1 system in the first year, which was due to the high initial cost involved in purchasing the BX-1 system components. However, from the second year onwards, the BX-1 system will have a cost-benefit saving of 76.9 % over the soil-polybag system for a minimum period of 8 years, as many components of the BX-1 system can re-used for a minimum of 8 years. In the soil-polybag system, labour was the main challenge which accounted for more than 90% of the total cost involved in the system. In conclusion, the research showed the influence of nutrients and water in the growth of rubber seedlings, with the BX-1 systems giving the highest growth parameters. The research also confirmed that different irrigation system removes different amount of nutrients and the best irrigation system to be used in BX-1 system and soil-polybag system was the capillary wick system as it gave the lowest leachate amount compared to others. Soil-polybag system of raising rubber seedlings was the best as it saved more cost than the BX-1 system in a small scale production, but it is advisable to use BX-1 system in a large scale production as the high initial cost of the system will be recovered.

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

PENGARUH TEKNIK PENYEDIAAN ANAK POKOK DAN SISTEM PENGAIRANNYA PADA TUMBESARAN, KEBERKESANAN PENGGUNAAN AIR DAN KANDUNGAN NUTRIEN OLEH POKOK GETAH (*Hevea brasiliensis* MUELL.ARG)

Oleh

ABBA NABAYI

April 2016

Pengerusi : Christopher Teh Boon Sung, PhD
Fakulti : Pertanian

Getah (*Hevea brasiliensis*) adalah tanaman penting di negara-negara Asia tropika. Di Malaysia, getah banyak menyumbang kepada ekonomi negara melalui pengeluaran susu getah. Pengeluaran susu getah memerlukan biji benih yang bebas dari penyakit, cepat matang dan mempunyai kadar kelangsungan hidup di lapangan yang tinggi. Walau bagaimanapun, pengeluaran biji benih di tapak semaian dikaitkan dengan kos pengairan air dan tenaga kerja. Anak-anak pokok yang kurang sihat yang cenderung untuk mengambil masa yang lebih lama di ladang sebelum dapat digunakan. Sistem BX-1 (tiub PK 900 dan media tanaman BX-1) adalah satu sistem penanaman baru tapak semaian yang diperkenalkan oleh Humibox Sdn. Bhd. dengan tujuan menggantikan cara konvensional (polibeg dengan tanah) untuk membesarkan biji benih. Bagi menangani masalah ini, kajian telah dijalankan di rumah lindungan hujan pada Ladang No. 15, Fakulti Pertanian, Universiti Putra Malaysia. Rawatan adalah: sistem BX-1 dengan sprinkler (T1), sistem BX-1 dengan pengairan titisan (T2), sistem BX-1 dengan capillary wick (T3) dan tanah-polibeg dengan capillary wick (T4), sebagai kawalan. Rawatan yang disusun atur dalam reka bentuk RCB dengan setiap 3 ulangan dan data telah di pungut setiap bulan selama 8 bulan. Objektif pertama kajian ini adalah untuk menentukan pengaruh sistem pengairan yang berbeza pada pertumbuhan anak benih getah dan kandungan nutrien daun (N, P, K, Ca, dan Mg). Hasil kajian menunjukkan bahawa sistem pengairan yang berbeza telah mempengaruhi pertumbuhan dan kandungan nutrient daun dengan signifikan ($P < 0.01$) dengan nilai-nilai yang lebih tinggi dalam pengairan titisan (T2) dan sistem capillary wick (T3), dan nilai-nilai yang lebih rendah dicatatkan dalam sistem sprinkler dan kawalan (tanah-polibeg). Ini disebabkan oleh kandungan nutrien yang lebih tinggi daripada BX-1 media yang 4 kali lebih daripada dalam tanah. Media tanaman BX-1 dapat mengurangkan penggunaan baja mineral. Objektif kedua kajian ini bertujuan untuk mendedahkan pengaruh sistem pengairan yang berbeza dalam nutrient melalui larut lesap (N, P, K, Ca, dan Mg), produktiviti air dan kecekapan penggunaan air benih getah. Keputusan menunjukkan bahawa sistem sprinkler (T1) menghilangkan jumlah nutrien yang tertinggi terutamanya untuk nutrien mudah alih (seperti N dan K), manakala kawalan (T4) adalah paling kurang menghilanghan nutrien. Jumlah nutrien

yang lebih rendah dihilangkan dalam kawalan adalah disebabkan oleh kandungan nutrien yang redah di dalam tanah. Produktiviti air yang lebih tinggi dicatatkan pada sistem pengairan titisan dan capillary wick, yang berbeza dengan ketara dengan sprinkler dan kawalan, tetapi dari segi kecekapan penggunaan air, yang tertinggi dicatatkan di dalam T4 (kawalan) adalah disebabkan oleh jumlah leachate yang sedikit dicatatkan pada sistem kerana kekonduksian hidraulik yang lebih rendah daripada tanah berbanding dengan media BX-1 yang semakin meningkat. Objektif ketiga ialah untuk menentukan analisis kos faedah antara kedua-dua sistem penanaman yang berbeza (BX-1 sistem dan sistem tanah-polibeg) meningkatkan benih semaian getah di 100 m^2 kawasan. Analisis menunjukkan bahawa sistem tanah-polibeg mempunyai perbelanjaan dan kos-faedah jumlah penjimatan sebanyak 92.5 dan 32% masing-masing, ke atas sistem BX-1 pada tahun pertama, ini adalah disebabkan oleh kos permulaan yang terlibat adalah tinggi dalam pembelian komponen sistem BX-1. Walau bagaimanapun, dari tahun kedua dan seterusnya, sistem BX-1 akan mempunyai penjimatan kos faedah 76.9% ke atas sistem tanah-polibeg untuk tempoh sekurang-kurangnya 8 tahun, kerana banyak komponen sistem BX-1 boleh digunakan semula untuk sekurang-kurangnya 8 tahun. Dalam sistem tanah-polibeg, buruh adalah cabaran utama yang menyumbang lebih daripada 90% daripada jumlah kos yang terlibat di dalam sistem. Kesimpulannya, kajian menunjukkan pengaruh nutrien dan air dalam pertumbuhan anak benih getah, dengan sistem BX-1 memberikan parameter pertumbuhan tertinggi. Kajian ini juga mengesahkan bahawa sistem pengairan yang berbeza mengeluarkan sejumlah kuantiti nutrien yang berbeza dan sistem pengairan yang terbaik untuk digunakan dalam sistem BX-1 dan sistem tanah-polibeg adalah sistem sumbu kapilari kerana ia memberi jumlah larut resapan yang rendah berbanding yang lain. Sistem tanah-polibeg membesarkan anak benih getah adalah yang terbaik kerana ia dapat menjimatkan kos lebih daripada sistem BX-1 dalam pengeluaran skala kecil, tetapi adalah dinasihatkan untuk menggunakan BX-1 sistem dalam pengeluaran berskala besar supaya kos permulaan system akan diperoleh semula.

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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:

Christopher Teh Boon Sung, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Ahmad Husni bin Mohd Haniff, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Zulkefly bin Suleiman, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

____
BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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Signature : ______________________
Name of Chairman of Supervisory Committee : Christopher Teh Boon Sung, PhD

Signature : ______________________
Name of Chairman of Supervisory Committee : Ahmad Husni bin Mohd Haniff, PhD

Signature : ______________________
Name of Chairman of Supervisory Committee : Zulkefly bin Sulaiman, PhD

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LIST OF ABBREVIATIONS

AA	Auto Analyser
AAS	Atomic Absorption Spectrophotometer
ANOVA	Analysis of Variance
CEC	Cation Exchange Capacity
CTRL	Control
DOA	Department of Agriculture
DRP	Drip irrigation system
EC	Electrical Conductivity
ET	Evapotranspiration
FC	Field Capacity
IRSG	International Rubber Study Group
MRB	Malaysian Rubber Board
PWP	Permanent Wilting Point
RCBD	Randomise Completely Block Design
RRIM	Rubber Research Institute of Malaysia
SAS	Statistical Analysis Software
SE	Standard Error
SNK	Student-Newman-Keuls
SPR	Sprinkler irrigation system
TDR	Time-Domain Reflectometry
USDA	United State Department of Agriculture
VMC	Volumetric Moisture Content

CHAPTER 1

GENERAL INTRODUCTION

Regional and global markets are driving the conversion of traditional agriculture and occupied non-agricultural lands to improve the production of permanent cash crops (Zhe and Jefferson, 2011). Rubber (*Hevea brasiliensis* [Muell. Arg.]) is an important plantation crop which has now spread over 10.3 million hectares globally, and it dominates the Asian region with 93% of the extent (IRSG, 2012). In tropical Asian countries, rubber is grown on highly weathered soils which are characterized by very low organic C contents (Zhang *et al.,* 2007) due to intensive cultivation for a long period of time. Maintaining an appropriate level of soil organic matter and biological cycling of nutrients is necessary to the success of any soil management in the humid tropics. Latex production lies in the development and distribution of seedlings that are early maturing, disease free and vigorous that could ensure high field survival rate. This can be achieved by proper soil fertility management in the nursery where these seedlings are produced (Waizah *et al.,* 2011). Rubber nurseries in the past were raised mostly in a newly cleared forest because of the availability of plants nutrients elements, but over time, the situation changed due to the conversion of the forest to industry use, which forced people to develop an option for raising rubber seedlings. Raising of young rubber plants (seedlings) is usually conducted in the nursery where they undergo necessary and desired manipulations (such as budding) (Aghughu and Oghide, 2012). A nursery is established to produce genuine quality and healthy planting materials with least expanses (*i.e* labour and cost) and at the earliest time possible.

A medium for plant growth potential for producing crops is largely determined by the environment that the soil or media provides for root growth. Roots need air, water, nutrients and adequate space to developed, as such, the plant growth is significantly controlled by the variation in the nutrient content of the media (Nageswara and Jessy, 2007). Contrary to soil chemical properties that are dynamic in nature, manufactured media chemical properties are expected to be rather constant. Selecting the most suitable growing media for the achievement of a successful plant production will be very important in tube (root trainer) growth (Nageswara and Jessy, 2007). Three functions of growing media are to support plant physically, to hold and provide water and nutrients elements and to enable plant roots get sufficient amount of oxygen (Ingram *et al*., 2003). A good growing media should not only supply physical, chemical and biological characteristics required by plant but also provide the conditions for practical plant production (*i.e*. root examining) (Sahin and Anapali, 2006).

Peat constitutes one of the principal raw materials that have been used in both container and cells for soilless crop production. Peat is used for the production of quality seedlings with objective of establishing morphological and physiological guarantee of successful crop growth following the transplant process (Lazcano *et al*., 2009). Soilless media are being used in production of seedlings. Plants needs media with good aeration, water retention capacity and fertilization routine to guarantee steady supply of nutrients (Macz *et al*., 2001).

BX-1 growing media comes from Latvia (PeltrAcom; a company in Latvia). The main composition is 100% neutralized white peat and it is suitable for growing media for rubber seedling production. BX-1 media has been treated with lime and slow releasing fertilizer. According to Herrmann and Bucksch (2014) white peat is defined as younger moss peat. Young moss peat is incompletely decomposed mosses, which grow in acidic environment of peat lands and raised bog (Blievemicht *et al*., 2011).

The growth of rubber seedlings is greatly influenced by the condition of their production. The factors affecting the production of rubber seedlings includes: the quality of the growing medium, irrigation, drainage and fertilization. Prosperous greenhouse and nursery production of container grown seedlings is largely dependent on the chemical and physical characteristics of the growing media (Robbins and Evans, 2011). An ideal potting medium should be weeds- and disease-free, heavy enough to prevent frequent tipping over and yet light enough to ease handling and shipping. The growing media should also be well drained and yet retain significant water to limit the irrigation frequency. Other factors to consider include cost, availability, wettability as well as stability of the media over time.

RB 900 is a root trainer developed by Humibox Sdn. Bhd., this root trainer is a single tube and was used specifically for growing rubber seedling.

Figure 1.1: RB900 tube (Courtesy of Humibox)

The tube dimension is 67.0 × 22.9 × 290.0 mm. RB 900 has thickness of 2.0 mm and the volume of this tube is 710 ml. Essentially, the theory behind use of these types of containers is that, with minimum root disturbance and exposure, higher growth and survival rate of the seedlings will be obtained because of the minimal transplanting shock (Kinghorn, 1974).

The most limiting and most variable environmental factor affecting productivity of plants is water. Agricultural plants need warm temperatures, sunlight, nutrients and water to grow. In many regions of the world the required temperature and sunlight are available but water is not. All plants have a minimum annual water requirement to survive and an optimal annual water requirement for maximum production (Field and Solie, 2007).

Efficient use of water by irrigation is becoming increasingly important, and alternative water application methods such as drip, capillary wick and sprinkler, may contribute substantially to the best use of water for agriculture and improving irrigation efficiency. Irrigation scheduling is very important (MetinSezen *et al*., 2006). With the help of proper irrigation systems, the problem of low productivity can be overcome. Climate change, water supply limits and continued population growth have intensified the search for measures to conserve water for irrigating crops, which is the world's largest water user (Field and Solie, 2007). Policy measures that encourage adoption of water-conserving irrigation technologies are widely believed to make more water available for cities and the environment (Ward and Pulido-Velazquez, 2008).

Plant growth can be defined as the irreversible changes with time which are mainly in size, often in form, and occasionally in number (Hunt, 2012). Plant growth quality and quantity depend on cell division differentiation and enlargement, which are ultimately affected by water stress (Cabuslay *et al.,* 2002; Correia *et al.,* 2001). It also reduced plant growth inhibition of many biochemical and physiological processes such as respiration, photosynthesis, translocation, ion uptake, nutrients, hormone and carbohydrate metabolism (Bhatt and Srinivasa, 2005; Chaitanya *et al.,* 2003; Blum, 1996).

Very little research on the water requirements of rubber has been reported with maximum actual evapotranspiration rates reported by many researchers as 3 mm day^{-1} which is lower than expected for a tree crop growing in the tropics (Carr, 2012). The daily ET rate of the clone RRIM 600 grown under glass house in Malaysia was found to differ from 2.1 to 6.9 mm day^{-1} (Haridas, 1980). Viijayakumar et al. (1998) stated that under field conditions, the averaged ET rate over 21 months was found to be 4.4 mm day^{-1}.

1.1 Justification

In Malaysia, there are no alternative techniques for establishing rubber seedlings in the nursery apart from the conventional one (soil-polybag), though compost is being used recently but still there is no established techniques for raising rubber other than the conventional system. Labour is the main limiting factor in the conventional system as it comprised of not less than 80% of the total cost involved in the nursery production system. Irrigation water is often in short supply, and the conventional system of irrigating the rubber seedlings is sprinkler which loss a lot of water and hence the need to have an alternative irrigation method. There is higher cost of the irrigation water and different irrigation systems have different water loss. BX-1 growing media was formulated purposely for raising rubber seedlings but there is no proper trial conducted on its performance on the rubber seedlings growth.

1.2 Problem statement

The conventional container used for seedling planting is polythene bag (polybag) with soil as its medium for growth. BX-1 system (RB 900 and BX-1 growing media) is a new nursery planting system introduced by Humibox Sdn. Bhd. with the purpose of replacing the traditional (Soil-polybag) system of raising seedlings. The introduction of BX-1 system should bring many benefits such as: lighter in weight and more compact and eco-friendly as the container can be reused, improved root growth, and reduction in labor work due to more efficient design and easier handling. In contrast, the usual conventional polybag causes negative impacts to environment because the polybag cannot be reused and takes longer time to disintegrate, the use of more space and a heavier media because soil is used as the growing medium.
There is no scientific research on the effectiveness of RB 900 root trainer and BX-1 growing media in plants water uptake and loss of nutrients through leaching. There was also no available information on water requirement by BX-1 system specifically for the production of rubber (*Hevea*) seedlings.

1.3 Aims and Objectives

1.3.1 Aim

In this study, the BX-1 system with three systems of irrigation (sprinkler, drip and capillary wick) will be evaluated on the growth, water-use efficiency and nutrient content of rubber (*Hevea brasiliensis*).

1.3.2 Objectives

The specific objectives are to compare the irrigation systems in terms of their effect on:

1. Rubber seedling growth and rubber leaf nutrient contents and uptake of N, P, K, Ca, and Mg.
2. Nutrient leaching loss (N, P, K, Ca, and Mg), water productivity and water use efficiency of different treatments
3. Cost benefit comparison between BX-1 system and soil-polybag system.

1.3.3 Research Hypothesis

1. Different irrigation system will influence the rubber seedlings growth parameters, growth analysis and leaf nutrient content differently.
2. Different amount of nutrients is expected to be leached by different treatments, with the highest under sprinkler system and lowest in the capillary wick irrigation system. highest water use efficiency and productivity are expected be different with the highest in the water saving irrigation systems.
3. Cost benefit is expected to be different with the highest under the BX-1 growing system, because of the higher number of seedlings that can be obtained in a small area in the system as compared to the conventional growing system.

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