
**UNIVERSITI PUTRA MALAYSIA**

# USE OF DATE PALM TRUNK AS ARID SANDY SOIL AMENDMENTS FOR EARLY GROWTH OF OKRA [*Abelmoschus esculentus* (L.) Moench]

**MARYAM HAROON AL-SOUFI**

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By

MARYAM HAROON AL-SOUFI

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the requirement for the degree of Doctor of Philosophy

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**Chair : Rosimah Nulit, PhD**
**Faculty : Science**

Cultivation in barren soils such as arid soil which covers around 12% of the earth's surface offers a potential remedy for the alarming global food-shortage. Improving infertile arid soil quality mainly its water holding capacity (WHC) can be done for crop production purposes and agricultural water conservation in arid regions with limited irrigation water resources. One of the common for WHC enhancement is using soil amendments including organic wastes such as biochar and date peat. Therefore, this study uses waste trunk of two major date palm (*Phoenix dactylifera* L.) cultivars, Khunaizi (KZ) and Khalas (KS) from the eastern region of Saudi Arabia to develop semi-powder form trunk used as organic amendment and mixed with arid soil from the Fodah district to develop and charasteised trunk mixtures used as a medium for the early growth of *Abelmoschus esculentus* (okra). The experiment was laid out in a randomized complete block design with three replicates. KZ and KS trunks were ground by multistage mill to particle size around 880 µm. Then, chemical (toxicity test, extractable nutrients and pH measurement, high cation exchange capacity, and thermogravimetric analysis), physical (sieve analysis, bulk density, porosity, and water retention), and biological (microbial enumeration) properties of all these samples were determined. Samples of KZ and KS were mixed with sandy soil at four application rates (25, 50, 75, 100 % w/w) and 10 % w/w of organic fertilizer (sheep manure) was added to each mixture. These was followed by cultivating okra seed in these processed mixtures along with individual controls of sandy soil, multi-soil, a commercial growth media, and KS and KZ amendments. During the cultivation stage, the following growth parameters were measured (seed germination duration, root length, plant height, leaf surface area, leaf numbers, assessment of chlorophyll, total soluble sugar, total protein contents, and WHC to assess the efficiency of the early growth of okra in the developed trunk mixtures. KZ and KS at 100% rate resulted in the lowest okra growth rate and higher preparation cost

therefore, they are not recommended. Whereas 25% is the optimal amendment rate resulting in optimal fertility characteristics including lower bulk densities of 40% for KZ and 36.6% for KS and higher porosity rates of 45.7% for KZ and 41.2% for KS compared to sandy soil control, higher early growth rate of okra, and the lowest preparation cost. Multi-soil samples showed higher growth rate than KZ and KS for roots density, sugar content, okra height, and leaf surface area that were possibly attributable to higher NPK content. Therefore, higher than 10% w/w of organic fertiliser is recommended to be added to KZ and KS mixtures. Field capacity, permanent wilting point, available water for plant were significantly higher for KZ amendments at 114%, 52%, 62% and for KS 118%, 52%, 65% compared to 7%, 3%, 5% for sandy soil control. Some of study analyses such as available water for plant and most of okra growth parameters such as germination percentage show insignificant results for both KZ and KS. Whereas some other study analyses such pH, and porosity show significant difference between KZ and KS. Although they were cultivars for date palm, they have some non-similar characteristics which may affect their suitability as growth media for okra. This study shows that the four mixtures of KZ and KS showed significant growth rate of okra for root length, sugar content, seed germination, and high WHC (4.7-17.7 %) with 3.6-10% increase on WHC compared to control sandy soil samples and comparable (16 %) to the commercial multi soil media. This can be explained by the natural fibre properties of trunk, elemental composition, morphological structure such as its high hydroxyl groups (OH) content and its hollow tubular structure. Therefore, KZ and KS are recommended as soil amendments and as alternatives to imported expensive commercial growth media due to their low cost, availability and abundance of date-palm cultivation in some Middle East countries such as Saudi Arabia. They can also be used as a sustainable and environment-based solution for combating desertification, water scarcity, and wastes accumulation particularly in arid regions by improving arid soil low productivity and fertility mainly WHC. Finally, it is recommended to extend this study for the cultivation of a wide range of the same plant family.

**Keywords**: Khunaizi, Khalas, date-palm trunk, sandy soil, multi soil, okra

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**PENGGUNAAN BATANG POKOK KURMA UNTUK PENAMBAHBAIKAN TANAH BERPASIR UNTUK PERTUMBUHAN AWAL OKRA [*Abelmoschus esculentus* (L.) Moench].**

Oleh

**MARYAM HAROON AL-SOUFI**

**September 2019**

**Pengerusi : Rosimah Nulit, PhD**
**Fakulti : Sains**

Penanaman di tanah yang tandus seperti tanah kering yang merangkumi sekitar 12% permukaan bumi mempunyai potensi untuk menyelesaikan masalah kekurangan makanan dunia yang membimbangkan. Peningkatan kualiti tanah gersang yang tidak produktif terutamanya kapasiti menampung air ("WHC") boleh dilakukan untuk tujuan pengeluaran tanaman dan pemuliharaan air pertanian di kawasan-kawasan yang gersang dengan sumber pengairan terhad. Salah satu sumber untuk peningkatan "WHC" menggunakan pindaan tanah termasuk sisa organik seperti biochar dan sisa kurma. Oleh itu, kajian ini menggunakan sisa batang dua pokok kurma utama (*Phoenix dactylifera* L.) dari wilayah timur Arab Saudi sebagai pindaan organik untuk tanah kering dari daerah Fodah untuk meningkatkan "WHC" dan menjadikannya sesuai untuk pertumbuhan awal *Abelmoschus esculentus* (okra). Eksperimen ini dibentangkan dalam reka bentuk blok lengkap rawak dengan tiga replika. Batang Khunaizi (KZ) dan Khalas (KS) dikisar oleh pengisar berperingkat kepada saiz zarah sekitar 880 µm. Kemudian, sifat-sifat kimia (ujian ketoksikan, nutrien yang boleh ekstrak dan pengukuran pH, kapasiti pertukaran kation yang tinggi, dan analisis termogravimetrik), fizikal (analisis ayak, ketumpatan pukal, keliangan dan pengekalan air) dan biologi (penghitungan mikrob) untuk semua sampel ini ditentukan. Sampel KZ dan KS dicampurkan dengan tanah berpasir pada empat kadar campuran (25, 50, 75, 100% w / w) dan 10% w / w baja organik (baja biri-biri) telah ditambah kepada setiap campuran. Kajian ini diikuti dengan menanam biji okra dalam campuran yang diproses bersama-sama dengan kawalan individu tanah berpasir, tanah-bercampur, media pertumbuhan komersil, dan pindaan KS dan KZ. Semasa peringkat penanaman, parameter pertumbuhan berikut diukur (tempoh percambahan benih, panjang akar, ketinggian tumbuhan, kawasan permukaan daun, bilangan daun, penilaian klorofil, jumlah gula larut, jumlah kandungan protein dan "WHC") untuk menilai kecekapan pertumbuhan awal okra dalam

campuran pertanian yang diproses. KZ dan KS pada kadar 100% menghasilkan kadar pertumbuhan okra terendah dan kos penyediaan yang lebih tinggi oleh itu, kadar campuran ini tidak digalakkan. Manakala, kadar pindaan sebanyak 25% adalah kadar pindaan optimum yang menghasilkan ciri-ciri kesuburan yang optimum, kadar pertumbuhan awal okra yang lebih tinggi, dan kos penyediaan terendah. Pada 25% daripada pindaan Khunaizi dan Khalas, kepadatan pukal adalah 40% dan 36.6% lebih rendah masing-masing, manakala kadar keliangan masing-masing 45.7% dan 41.2% lebih tinggi. Sampel tanah-bercampur menunjukkan kadar pertumbuhan yang lebih tinggi daripada KZ dan KS untuk ketumpatan akar, kandungan gula, ketinggian okra, dan kawasan permukaan daun yang mungkin dikaitkan dengan kandungan NPK yang lebih tinggi. Oleh itu, baja organik yang lebih tinggi daripada 10% w / w disyorkan untuk ditambah kepada campuran KZ dan KS. Kapasiti lapangan, titik larutan kekal, air yang ada untuk tumbuhan adalah lebih tinggi untuk pembaikan KZ pada 114%, 52%, 62% dan untuk KS pada 118%, 52%, 65% berbanding 7%, 3%, 5% untuk tanah berpasir kawalan. Analisis kajian seperti kandungan air untuk tumbuhan, dan kebanyakan parameter pertumbuhan seperti peratus percambahan menunjukkan perbezaan yang tidak ketara antara KZ dan KS. Manakala, analisis yang lain seperti pH dan keliangan menunjukkan perbezaan yang ketara antara KZ dan KS. Walaupun mereka adalah kultivar untuk kurma, mereka mempunyai ciri-ciri yang tidak serupa yang mungkin mempengaruhi kesesuaian mereka sebagai media pertumbuhan okra. Kajian ini menunjukkan bahawa pindaan tanah berpasir pada empat kadar campuran bagi KZ dan KS menunjukkan kadar pertumbuhan yang ketara bagi panjang akar, kandungan gula, percambahan benih dan “WHC” yang tinggi, (4.7-17.7 %) dengan peningkatan ke atas “WHC” sebanyak 3.6-10 % berbanding sampel tanah berpasir kawalan dan perbandingan (16 %) terhadap media tanah campuran komersial. Hal ini boleh dijelaskan oleh sifat serat semula jadi batang, komposisi unsur, struktur morfologi seperti kandungan hidroksil (OH) yang tinggi dan struktur tiub berongga. Oleh itu, KZ dan KS disyorkan sebagai tanah pindaan dan sebagai alternatif kepada media pertumbuhan komersil mahal yang diimport kerana kos yang rendah, ketersediaan dan jumlah tinggi penanaman kurma di beberapa negara seperti Arab Saudi. Ia juga boleh digunakan sebagai penyelesaian yang mampan dan berasaskan alam sekitar untuk memerangi penggurunan, kekurangan air dan pengumpulan sampah terutama di kawasan-kawasan yang gersang dengan menambahbaikkan tanah yang rendah produktiviti dan kesuburan terutamanya “WHC”. Kesimpulannya, adalah disyorkan untuk melanjutkan kajian ini untuk penanaman pelbagai spesies tumbuhan lain.

**Kata kunci**: Khunaizi, Khalas, batang pokok kurma, tanah pasir, tanah campuran, okra

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| | |
|---|---|
| $NH_3$ | Ammonia |
| AWC | Available water content |
| BSA | Bovine serum albumin |
| BS | British Standard |
| $Ca^{2+}$ | Calcium ion |
| $CaCO_3$ | Calcium Carbonate |
| C | Carbon |
| CEC | Cation Exchange Capacity |
| cmol | Centimole |
| cfu | Colony forming unit |
| Cu | Copper |
| m3 | Cubic meter |
| DPE | Date palm extract |
| DPBW | Date palm biomass wastes |
| DPT | Date Palm Trunk |
| ET | Evapotranspiration |
| °C | Degree Celsius |
| $ | Dollar |
| DMRT | Duncan's Multiple Range test |
| FC | Field capacity |
| GABA | Gamma-aminobutyric acid |
| GAMEP | General Authority of Meteorology and Environmental Protection |
| g | Gram |
| GHG | Greenhouse Gas |
| GCC | Gulf Cooperation Council |
| ha | Hectare |
| h | Hour |
| $H_3O^+$ | Hydronium |
| $H^+$ | Hydrogen ion |
| RILEM | International Union of Laboratories and Experts in Construction Materials, Systems and Structures |
| Fe | Iron |
| KS | Khalas |
| KZ | Khunaizi |
| kg | Kilogram |
| kPa | Kilopascal |
| KSA | Kingdom of Saudi Arabia |
| LSR | Leaf Surface Area |
| l | Liter |
| lux | Luminous flux per unit area |
| $Mg^{2+}$ | Magnesium ion |
| Mn | Manganese |
| $CH_4$ | Methane |
| µm | Micrometer |

| | |
|---|---|
| meq | milliequivalent |
| mg | Milligram |
| mm | Millimeter |
| mM | Millimolar |
| min | Minutes |
| MSW | Municipal Solid Waste |
| nm | Nanometer |
| N | Nitrogen |
| $N_2O$ | Nitrous oxide |
| RPE | Particularly respiratory protection equipment |
| % | Percentage |
| PPE | Personal protective equipment |
| P | Phosphorus |
| K+ | Potassium ion |
| PC | Pot capacity |
| pH | Potential hydrogen |
| RPW | Red palm weevil |
| RILEM | Reunion Internationale des Laboratoires et Experts des Materiaux |
| SPF | Semi Powder Form |
| Na+ | Sodium ion |
| SP | Soil porosity |
| SE | Standard Error |
| S | Sulphur |
| $ScCO_2$ | Supercritical carbon dioxide ($ScCO_2$) |
| TGA | Thermogravimetric analysis |
| t | Tones Per Hectare |
| Tris-HCl | Tris (hydroxymethyl) aminomethane |
| UAE | United Arab Emirates |
| UN | United Nations |
| UNCCD | United Nations Convention to Combat Desertification |
| UNCOD | United Nations Conference on Desertification |
| UPM | Universiti Putra Malaysia |
| USA | United States of America |
| VOCs | Volatile organic compound |
| WHC | Water holding capacity |
| WR | water retention |
| Y | Yard |
| Zn | Zinc |
| USDA | United States Department of Agriculture |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of the Study

There are numerous global challenges, and two of these that have essential economic, social, and environmental impact on the world are desertification and water scarcity (Longjun, 2011). Desertification is defined as "degraded land in arid, semi-arid and dry sub-humid areas," that are non-arable land because their soil is infertile soil with low productivity. Their low productivity is due to the soil's physiochemical characteristics such as low organic matter content (1-2%), and low water-holding capacity (WHC) leading to low soil quality and yield. An optimal soil structure for agricultural purposes is the soil known for its well-developed soil aggregates and pore system (Tahir & Marschner, 2016; Usowicz & Lipiec, 2017).

Water scarcity, the second challenge, is defined as "the lack of sufficient available water resources to meet the demand for water within a region." Water is essential for all living things and its scarcity results from the need of more water resources since not all available water resources are accessible for use, as most are low quality water. Moreover, water resources scarcity will increase because of growing energy demand, economic development, population as well as climate change (Brown, 2010; DeNicola, et al., 2015). Arid regions suffer from limited available water resources for consumption and agricultural applications. Combatting desertification, improving soil quality and productivity, and alleviating water scarcity have become a major global challenges to meet the increase in global food production mainly because of the world's increasing population (Usman et al., 2016; Medeiros, 2018). In addition to desertification and water scarcity, a million tons of biomass wastes such as date biomass wastes are produced annually and need to be treated because of their negative effect on the environment. Date biomass wastes generated in huge amounts in countries known for high date fruit production such as the Kingdom of Saudi Arabia (KSA), and are buried in landfills seriously threatening the health of humans and the environment (Brunetti, 2015; Sharifi, 2015). The high date palm biomass wastes disposal expenses, limited landfill used for waste disposal, their negative effects on the environment and humans, and the steady increase of global waste generation indicate the urgent need for waste utilisation (Al-Wabel et al., 2011; Johnson, 2012; AlHumid et. al., 2019).

To the best knowledge of this researcher, there has not been any study done to investigate the effect of using biomass wastes derived from date palm (*Phoenix dactylifera)* trunks as arid soil amendment or its characteristics, mainly WHC. Date palm biomass wastes can be used to treat and combat desertification and water scarcity.

## 1.2 Problem Statement and Justification of Study

An arid region poses several challenges such as infertile soil and water scarcity, which are the major obstacles to the need to raise the level of food production to feed the world's rapidly growing population. Hence, major solutions must be found and implemented such as improving the soil quality, enhancing efficiency in the economic utilisation of water, to enable increased crop productivity (Odofin et al., 2011). The conversion of infertile soil into productive fertile soil is necessary to combat desertification. This can be achieved by the implementation of several practices such as improving soil WHC. This can be further enhanced by the addition of soil amendments including biochar, and compost (Basso et al., 2013; Khalifa & Yousef, 2015). The enhancement of soil WHC will lead to less amount of water use by plants and is a viable approach to combat desertification and water scarcity. In addition to the two challenges, the high production of biomass wastes yearly such as a million tons of date palm wastes is in itself an environmental pollution dilemma (Brunetti, 2015; Sharifi, 2015). Waste generation will continue to occur worldwide (Ouda et al, 2016). Therefore, the treatment of these biomass wastes due to their negative impacts becomes essential. Utilisation of biomass wastes such as date palm trunk (DPT) to improve soil fertility is a promising way to treat these wastes. Furthermore, they can be used as a sustainable and environmentally friendly resource for improving soil quality and productivity to combat desertification and water scarcity (Hussain et al., 2014; Eom, 2015; Al-Kutti et al., 2017).

## 1.3 Objectives of Study

To date, not adequate attention has been given to the utilisation of biomass wastes including DPT for agricultural purposes. To the best knowledge of this researcher, no studies appear to have been done to explore the impact of using these wastes in improving soil quality and productivity mainly through its water holding capacity.

In light of the above scenario, the study objectives are:

1. To develop DPT in a semi-powder form derived from two date palm cultivars, KZ and KS.
2. To develop four mixtures of sandy soil amended with each of the developed KZ and KS.
3. To characterise the mixtures using biological, chemical, and physical analyses.
4. To verify the appropriateness of the mixtures as a medium for the early growth of okra.

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## BIODATA OF STUDENT

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## LIST OF PUBLICATION

AL-Soufi, M.H. and Nulit, R. (in press). The early growth of *Abelmoschus esculentus* L. (okra) using arid sandy soil amended with powdered date palm karab waste. Journal of Horticultural Science and Crop Research.