GROWTH AND YIELD OF PEARL MILLET (*Pennisetum glaucum* L.) USING JATROPHA CUTTINGS AND MINERAL FERTILIZER ON INCEPTISOLS OF SUDAN SAVANNA, NIGERIA

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

July 2022

FP 2022 73

DEDICATION

This work is dedicated to Almighty Allah (S.W.T), The Beneficient and The Merciful.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Faculty : Agriculture

Field trials were conducted in 2018 and 2019 rainy seasons to evaluate the growth, yield and nutrients (NPK) uptake of pearl millet (*Pennisetum glaucum* L.) as well as soil nutrients status in response to levels of jatropha cuttings (biomass foliage), mineral fertilizer and methods of application of jatropha cuttings, at two locations (Kadawa and Dutsinma) in the Sudan Savanna of Nigeria where affordability and accessability of fertilizer is difficult, hence low income farmers cultivate crops on low fertility soils (Inceptisols). To improve their fertility, these soils require input of large amounts of organic materials such as jatropha cuttings, which is a cheap and accessible resource. The treatments consisted of three levels of jatropha cuttings (0, 5 and 10 t ha^{-1}), three levels of mineral fertilizer (0, half and full recommended rate of 60 kg N ha^{-1}, 30 kg P_2O_5 ha^{-1}, 30 kg K_2O ha^{-1}) and two methods of application (incorporation and surface placement). Treatments were arranged in a Randomized Complete Block Design replicated three times. Jatropha cuttings and mineral fertilizer significantly ($p<0.05$) improved the growth and yield of pearl millet over control treatment. However, mineral fertilizer was mostly superior to jatropha cuttings in improving the yield and nutrient uptake of pearl millet. From 2018 to 2019, most growth and yield attributes of pearl millet were observed to increase. Significant increases mostly occurred in 2019 season probably due to carryover effect of nutrients. In 2019, incorporation of 10 t ha^{-1} jatropha cuttings led to significant increase in plant height (167.3-264.3 cm), leaf area (152.3-282.2 cm^2), grain yield (402.6-2192.9 kg ha^{-1}) and stover yield (3557.1-8939.3 kg ha^{-1}). Mineral fertilizer significantly improved plant height (167.3-223.7 cm), grain yield (402.6-3606.9 kg ha^{-1}), stover yield (4698.2-10570 kg ha^{-1}), and NPK uptake. Incorporation of jatropha cuttings was superior to surface placement in enhancing plant height (157.7-264.3 cm), leaf area (164-282.3 cm^2), grain yield (438.9-2192.9 kg ha^{-1}) and stover yield (3321.8-7461 kg ha^{-1}). Mostly, pearl millet's yields recorded positive and significant relationship with plant height, leaf area and nutrients uptake. Soil pH was significantly decreased by mineral fertilizer. Generally, surface application of jatropha cuttings significantly increased organic carbon, total nitrogen, pH and CEC. Mineral fertilizer significantly enhanced available phosphorus. Soil quality was improved by

combinations of surface applied jatropha cuttings plus mineral fertilizer. Soil fertility index (SFI) and soil evaluation factor (SEF) correlated positively and significantly with each other and with grain yield or available phosphorus. Significant interactions revealed that incorporation of 10 t ha^{-1} jatropha cuttings increased plant height (44-58%), leaf area (85.5%), grain yield (286.3%) and stover yield (109.8%). Combination of 10 t ha^{-1} jatropha cuttings plus half rate of mineral fertilizer was mostly at par with the full rate of mineral fertilizer. Combinations of mineral fertilizer and jatropha cuttings recorded benefit/cost ratios of >1.0. Therefore, surface application of higher rates (≥10 t ha^{-1}) of jatropha cuttings in combination with modest amounts (half recommended rate) of mineral fertilizer can sustainably improve soil fertility and pearl millet productivity in Inceptisols area of Sudan Savanna (Nigeria).

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

PERTUMBUHAN DAN HASIL TANAMAN SEKOI (*Pennisetum Glaucum* L.) MENGGUNAKAN SISA POTONGAN POKOK JARAK (*Jathropa*) DAN BAJA MINERAL DI TANAH INSEPTISOL DI SUDAN SAVANNA, NIGERIA

Oleh

ABDULLAHI NURADDEEN ALIYU

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Kajian lapangan telah dilaksanakan pada musim hujan 2018 dan 2019 untuk menilai pertumbuhan, hasil dan serapan nutrien (NPK) bagi tanaman Sekoi Mutiara (*Pennisetum glaucum* L.) serta status nutrien tanah sebagai tindak balas terhadap tahap keratan pokok jatropha (biojisim dedaun), baja mineral dan kaedah taburan keratan pokok jatropha di dua lokasi (Kadawa dan Dutsinma) di Sudan-Savana (Nigeria) di mana kemampuan membeli dan kemudahan memperolehi baja adalah sukar. Oleh itu, petani berpendapatan rendah terpaksa mengusahakan tanaman di tanah berkesuburan rendah (Inceptisols). Untuk meningkatkan kesuburan tanah, memerlukan pelbagai bahan organik seperti biojisim dedaun pokok jatropha yang merupakan sumber yang murah dan mudah didapati. Rawatan kajian merangkumi tiga paras jisim pokok jatropha (0, 5 dan 10 t ha^{-1}), tiga paras baja mineral (0, pada kadar separuh dan penuh disyorkan bagi 60 kg N ha^{-1}, 30 kg P_2O_5 ha^{-1}, 30 kg K_2O ha^{-1}) dan dua kaedah taburan (penggabungan dan penempatan permukaan). Rawatan disusun di dalam Blok Lengkap Rawak yang diulang sebanyak tiga kali. Keratan pokok jatropha dan baja mineral dengan ketara meningkatkan ($p<0.05$) pertumbuhan dan hasil sekoi mutiara melalui rawatan terkawal. Namun, baja mineral didapati lebih berkesan berbanding keratan pokok jatropha dalam meningkatkan hasil dan serapan nutrien sekoi mutiara. Dari 2018 hingga 2019, kebanyakan pertumbuhan dan hasil sekoi mutiara didapati meningkat. Peningkatan yang ketara kebanyakannya berlaku pada musim 2019; ini mungkin disebabkan oleh kesan pemindahan nutrien. Pada 2019, penggabungan keratan pokok jatropha10 t ha^{-1} meningkatkan ketinggian pokok (167.3-264.3 cm), keluasan daun (152.3-282.2 cm^2), hasil bijirin (402.6-2192.9 kg ha^{-1}) dan hasil batas (3557.1-8939.3 kg ha^{-1}). Baja mineral secara ketara meningkatkan ketinggian pokok (167.3-223.7 cm), hasil bijirin (402.6-3606.9 kg ha^{-1}), hasil batas (4698.2-10570 kg ha^{-1}), dan serapan NPK. Penggabungan keratan pokok jatropha adalah lebih berkesan pada penempatan permukaan dalam meningkatkan ketinggian pokok (157.7-264.3 cm), keluasan daun (164-282.3 cm^2), hasil bijirin (438.9-2192.9 kg ha^{-1}) and hasil batas (3321.8-7461 kg ha^{-1}). Kebanyakannya, hasil bijian mutiara mencatatkan hubungan positif dan signifikan dengan ketinggian pokok, keluasan daun dan serapan nutrien. Penggunaan baja mineral menyebabkan

penurunun pH tanah secara signifikan. Secara amnya, meletakkan keratan pokok jatropha pada permukaan meningkatkan karbon organik, jumlah nitrogen, pH dan CEC dengan ketara sekali. Baja mineral didapati meningkatkan fosforus sedia ada dengan ketara. Kualiti tanah dipertingkatkan dengan menaburkan gabungan biojisim pokok jatropha dan baja mineral pada permukaan. Indeks kesuburan tanah (SFI) dan faktor penilaian tanah (SEF) berkolerasi secara positif dan signifikan antara satu sama lain serta dengan hasil bijian atau dengan fosforus sedia ada. Interaksi yang signifikan ini menunjukkan gabungan 10 t ha^{-1} keratan pokok jatropha meningkatkan ketinggian pokok (44-58%), keluasan daun (85.5%), hasil bijian (286.3%) dan hasil batas (109.8%). Gabungan 10 t ha^{-1} keratan jatropha yang ditambah dengan separuh kadar baja mineral kebanyakannya setara dengan kadar penuh baja mineral. Gabungan baja mineral dan keratan jatropha mencatatkan nisbah faedah/kos >1.0. Oleh itu, taburan permukaan pada kadar yang lebih tinggi (≥10 t ha^{-1}) keratan pokok jatropha dengan gabungan baja mineral pada tahap sederhana (kadar separuh yang disyorkan) boleh meningkatkan kesuburan tanah dan produktiviti sekoi mutiara di tanah Inceptisols bagi kawasan Sudan Savana (Nigeria).

ACKNOWLEDGEMENTS

I am most grateful to Almighty Allah (S.W.T), The Most Beneficient and The Most Merciful for everything. My sincere appreciation goes to my dissertation supervisory committee chairman, Dr. Roslan Bin Ismail who patiently supervised this work in detail with much insight, guidance, constructive-critism, encouragement and open-minded approach during my whole PhD program. May Almighty Allah (S.W.T) re-bless you ever much more for the sake of Prophet Muhammad Rasulullah (S.A.W). I am very grateful to members of my supervisory committee; Dr. Martini Binti Mohammad Yusoff, Dr. Mohammad Firdaus Bin Mohammad Anuar and Associate Professor Garba Adamu K/naisa who have worked tirelessly in contributing to all processes involved in this research work. They were indeed supportive and friendly all along. May Allah (S.W.T) continue to reward them abundantly (Ameen). I thank Prof. Kamal Uddin, Prof. Christopher Teh Boon Sung (HOD), Prof. Samsuri Abd Wahid, Prof. Somchai Anusontpornperm and all staff of the Department of Land Management for their contribution in on way or the other towards the success of this work. My gratitude goes to the authorities of Isa Kaita College of Education, Dutsima, Katsina state and the Tertiary Education Trust Fund (Tetfund) for moral and financial support to undertake this study. In particular, I thank Dr. Maigari Abdu (Former Provost), Dr. Samaila Ado (Provost), Alh. Salisu Gide (Registrar), Dr. Musa Usman Mani, Prof. Bitrus Tarfa (A.B.U), Prof. Ahmad Bakori and Prof. Salisu Muhammad (B.U.K) who have been very kind to me. I appreciate the great care, patience and courage by my late Father (Alh. Abdullahi Aliyu Bakori), my Mum (Hajia Rabi'atu Ado), my wife (Hajia Binta Hussain), my children: Zara, Muhammad, Ruqayya, Abdullahi and Ahmad, my brothers (Shamsuddeen and Ibrahim), sisters and cousins. May Allah (S.W.T) bless them all. I also thank my friends and colleages who have been instrumental in many aspects of this work including: Miss Adila (Secretary to Dr. Roslan), Rabi'u Sani (A'u), Sani Abdullahi, Kabir Adebayo, Jamilu Halidu, Auwal Garba Gashua, Dr. Badamasi Sani Kurna, Ibrahim Abdullahi (Babankowa), Babangida Milo, Tijjani Abu Rimi, Abdulmalik Nabukka (FUDMA), Abdullahi Salisu, Suleman Kebbi, Shuaibu Zamfara, Saifulislam, Motassim, Kasim, Rizwan, Mal. Muttaka (Dean), Mal. Abdullahi Daura, Alh. Hussain Idris, Alh. Bashir Sadiq, Mal. Mustafa Ahmad, Mal.Umar Ibrahim (HOD), Mal.Sani Ibrahim, Anas Knk, Idris Knk, Aliyu Dauda Bkr, Baba Shuaibu Hassan, Mustafa Ado, Abu Mohammed, Kabir Ladan, Ado Ibrahim, Kabir Mato, Musa Isa, Major Adam Bkr, Ibrahim Inusa, Ashiru Malam Bkr and Mal. Ilu of A.B.U. Zaria

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

AAS	Atomic Absorption spectrophotometry
ANOVA	Analysis of Variance
Exch.	Exchangeable
Frate	Rate of mineral fertilizer
$Full_{rrf}$	Full Recommended Rate of mineral Fertilizer
$Half_{rrf}$	Half Recommended Rate of mineral Fertilizer
HSD	Tukey's Honestly Significant Difference
I	Incorporation
Jrate	Rate of jatropha cuttings
JxF	Interaction between jatropha cuttings and mineral fertilizer
LOS	Level of Significance in statistics
Method	Application method of jatropha (incorporation or surface placement)
MxF	Interaction between method of application and mineral fertilizer
MxJ	Interaction between method of application and jatropha cuttings
MxJxF	Interaction among method of application and jatropha and fertilizer
₦	Naira (Nigerian currency, USD:₦ is 1:360)
NAPRI	National Animal Production Research Institute, Nigeria
NS	Not Significant
S	Surface placement
SE	Standard Error
SEF	Soil Evaluation Factor
SFI	Soil Fertility Index
T	Treatment
WAS	Weeks After Sowing

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Pearl millet (*Pennisetum glaucum* L.) is a member of the Poaceae family of grasses and has been used as food for over 10, 000 years (Martins *et al.*, 2018). In many tropical areas, it is among the first four most important cultivated crops (rice, maize, sorghum and millet) and more than 100 million people consume it as staple food (Earl, 2018). Pearl millet is highly adapted to high temperature, low soil fertility, low pH, and high salinity and drought conditions when compared to maize or sorghum (ICRISAT, 2018). Nutritionally, the National Academy of Sciences (2018) submitted that 70% of pearl millet's dry grain is starch, up to 21% protein, approximately 5% fat while ash comprises about 3%. It also contains vitamins and many minerals such as phosphorus (339 mg), Iron (16.9 mg) Calcium (37 mg) and traces of Barium, Chromium, Cobalt, Copper, Manganese, Molybdenum, Nickel, Titanium, Vanadium, Zinc and Iodine. However, low soil fertility has been identified as one of the factors that limit pearl millet productivity (ICRISAT, 2018). Furthermore, Bhuva *et al*. (2018) indicated that nutrient management plays a vital role in increasing the productivity of pearl millet.

In Nigeria, pearl millet is highly consumed by the community (over 40 million people) to the extent that annually, over 4 million tonnes are consumed, while the country could only produce about 2 million tonnes (Mundi, 2020; FAO, 2018; Cheng and Catherine, 2016; Miller, 2016). This clearly highlights the gap between local demand and production level of such an important crop in Nigeria. Essentially, pearl millet is mostly cultivated in the dryer Northern parts of Nigeria such as Borno, Yobe, Adamawa, Kano, Katsina, Jigawa, and Sokoto states. Nutritional stresses due to low soil fertility are among the major constraints to higher pearl millet yields in Nigeria (Maryam *et al*., 2017). In order to boost the productivity of the crop, combined use of both mineral and organic resources have been found to be effective for sustained and increased performance (Divya *et al*., 2017).

The soils of Nigeria are known to be developed on weathered basement complex and sedimentary rocks (Idem and Shewemino, 2004). Specifically, the Nigerian Sudan Savanna is dominated by Inceptisols and Entisols which are soils that have developed recently with shallow, immature and weak horizon differentiation (Chude, 1998). The natural fertility of these soils has frequently been described by Singh (2015) and Brady and Weil (1999) as low or moderate or high due to the fact that their natural productivity varies considerably, depending on location and properties. Therefore, to properly manage these soils, there is need for addition of large amount of organic wastes and manures to act as fertilizers and soil amendments in order to produce crops, despite the obstacles to profile development (Miller and Donahue, 1992). Essentially, the Inceptisols of Nigerian Sudan Savanna region are mostly of the Tropepts sub order of soil taxonomy (Yusuf and Yusuf, 2008). They are described as light, shallow, sandy loam soils with

ochric epipedon that have low organic matter content and are formed under warmer soil temperature regimes (Grunwald, 2015).

In order to sustainably improve the Agricultural potential of such poor soils, many authors (Zant, 2014; Brady and Weil, 2008; Maundu and Tengnas, 2005; Eilitta *et al.,* 2004; Tarfa *et al.,* 2001; Vanlauwe *et al.,* 2001; Uyovbisere and Elemo, 2000) have indicated the benefits of using suitable, cheap and available organic materials such as foliage of trees or shrubs (e.g jatropha cuttings) for increased food production, especially in the Sub-Saharan African region where majority of the farmers are small scale producers and poverty among them is as well prevalent.

1.2 Problem statement

The roles of Jatropha in relation to plant and soil development have been studied by many researchers including; Hassan *et al.* (2013) who reported the allelophatic effect of Jatropha on germination and seedling development of millet, while Akanmu *et al*. (2014) examined the inhibition of Fusarium pathogens on millet by Jatropha and *Mangifera indica*, whereas Abugre, Yeboah, and Oti (2011) investigated the litter-fall decomposition trend of *Jatropha Curcas* L. leaves under open and closed canopies. Again, studies on the effect of distance from *J. curcas* hedgerow on growth and yield of *Zea mays* L. has been documented (Abugre, Obi-Boateng and Adu – Gyamfi, 2011). Furthermore, Chaudhary *et al*. (2014) determined the carbon and nitrogen mineralization potential of *J. curcas* residue in soil while Derra (2013) showed the management patterns of *J. curcas* regarding its impact on the microbial and mycorrhizal biomass in different phyto-geographic zones of Burkina Faso. The impact of Jatropha on soil fertility in Ethiopia was also reported by Habtamu (2011). The effects and potential of *J. curcas* cake on millet in Sahel were investigated by both Traore *et al.* (2015) and Traore *et al.* (2012) respectively. Effect of Jatropha based agroforestry on groundnut yield was studied by Ibrahima *et al*. (2017). Thus, a lot of work had been carried out on Jatropha in relation to various aspects of soil and plant development, however, detailed studies on the effect of Jatropha cuttings on the growth and yield of pearl millet in the Sudan Savanna area are limited in number, despite the fact that in the Nigerian Sudan Savanna, many small farmers fence their fields with *J. curcas* and millet is an important and widely grown crop in the study area that keeps recording small global average yield (0.8 t ha^{-1}) in the last 5 decades in comparison to maize (4.0 t ha^{-1}), rice (3.8 t ha^{-1}), wheat (2.6 t ha^{-1}) and sorghum (1.5 t ha^{-1}). This is attributable to little investment on pearl millet research programs that led to low use of agronomic techniques such as fertilizer management and mechanization and that was why this study tried to investigate the effect of Jatropha cuttings on the performance of pearl millet in Sudan Savanna (Inceptisol) of Nigeria which may heip in reducing the cost and adverse effects associated with the use of mineral fertilizers. for better environmental wellbeing and safety.

1.3 Study objectives

The major aim of this research work was to study the effect of Jatropha cuttings as soil amendment in the production of pearl millet under low soil fertility condition in Sudan Savanna of Nigeria. The specific objectives were: -

i. To determine the growth and yield of pearl millet under different rates of Jatropha cuttings and mineral fertilizer for identification of the appropriate combination to replace mineral fertilizer

ii. To determine millet yields under "soil incorporated" and "surface applied" Jatropha cuttings for understanding the superiority of each method

iii. To determine the effect of treatments (Jatropha cuttings and mineral fertilizer) on nutrients (NPK) uptake in relation to pearl millet yields.

iv. To determine soil nutrients status (soil quality) as influenced by the application of Jatropha cuttings and mineral fertilizer for observing trend in nutrients levels

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