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INFLUENCE OF *JATROPHA CURCAS* ON SOIL FERTILITY IMPROVEMENT OF DEGRADED SUDANESE SAVANNAH ALFISOLS

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Abstract
An attempt to provide solution to rapid soil fertility decline using biological inputs has led to the investigation of the influence of jatropha on improving soil fertility in the Sudan Savannah region of Nigeria. The excessive and unskilled use of chemical fertilizers and pesticides adversely affects the soil ecosystem, leading to a decrease in crop productivity and the production of potentially harmful food unsafe for human consumption. Thus, in this study, a nursery experiment was conducted at the Department of Forestry and Wild Life Management, Aliko Dangote University of Science and Technology, Wudil to assess the influence of Jatropha curcas plant on fertility improvement of degraded alfisol. The experiment was arranged in a completely randomized design (CRD) with 3 replications and controls. Pre- and post-Jatropha planting soil samples of Jatropha seeds and cuttings with and without organic amendment were analyzed for soil physicochemical fertility parameters. Findings indicated that at the pre- and post-Jatropha planting periods, the pH of the soils was within the range of 6.77-7.02 and their texture was sandy loam and loamy sand, respectively. Moreover, Jatropha cuttings and seeds with organic amendments (CO and SO) improved major soil fertility parameters; nitrogen content N, exchangeable bases (EB), organic carbon (OC), phosphorus (P), and cation exchange capacity (CEC) higher than Jatropha cuttings and seeds

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without organic amendments at the post-jatropha planting period compared with the pre-planting period. In addition, cuttings with organic amendment (CO) recorded the highest concentration of fertility improvement parameters compared with the latter and other treatments during the post Jatropha planting period. Statistically, both physical and chemical soil fertility parameters showed significant variation ($P<0.05$) with Jatropha plants in SO and CO treatments with major soil fertility parameters; OC, P, EB, and CEC at the post Jatropha planting period. Overall, the research findings have shown that Jatropha curcas is capable of improving the fertility of degraded marginal soils in the Sudan Savannah ecological zone, particularly if grown with cuttings and amended with organic amendments.

1.0 Introduction

In the Sudan Savannah region of Africa, soil productivity maintenance and improvement remains an issue due to poor unsustainable practices, coupled with the fragile nature of most soils (Oyetunji et al., 2001). Soil fertility depletion is considered the single most important constraint to food security in West Africa (Bationo et al., 2006). The reduction in tropical soil fertility has become a major concern and indeed a great impediment to achieving food security in the regions. However, continuous and exhaustive use of highly priced mineral fertilizers for improving crop productivity in the past decades has been obviously connected to this problem (Afe and Oluleye, 2017) and influences nutrient imbalances, leaching of nitrates and phosphates, marine eutrophication, and groundwater contamination through tributaries, microbial activities, soil acidity, and serious threats to human health. Although these chemical fertilizers increase soil nutrients as plants directly and indirectly assimilate the nutrients provided by their ready mineralization, their continuous long-term application impact various negative effects on the environment and ecosystem (Akbariyeh et al., 2018; Mahal et al., 2019).

The traditional way of using synthetic chemical fertilizers as a common fertilizer in most developing countries for crop production can no longer be depended on, especially as its use is being threatened with cost economics and absence when needed by farmers (Adeoluwa and Suleiman 2012) in addition to a negative impact on the receiving environment and ecosystem. Thus, a need to consider another source of fertilizer that is cheaper, biologically resourceful, has no residual harmful effect, and can replenish soil with the appropriate needed nutrients capable of improving soil fertility and quality, such as *Jatropha curcas* plants, becomes indispensable.

Jatropha curcas (henceforth denoted as Jatropha) is a drought-resistant oil-bearing multipurpose shrub/small tree belonging to the family Euphorbiaceae (Baroi et al., 2009; Mulpuri et al., 2019). The plant is fast growing and exhibit high biomass production ability (Ali et al., 2013), carbon sequestration capability, erosion control potential, and can increase soil fertility (Mohammed et al., 2021) with the ability to rehabilitate and improve soil fertility degradation, as well as soil and water conservation improvement (Pandey et al., 2012; Sani et al., 2022). Previous studies on jatropha plants in the Sudan Savannah region of Nigeria concerted their effort on the plant's ability to improve soil physical quality properties (Shehu et al., 2016) and the phytoremediation of contaminated soils (Abdullahi et al.,2017; Abdullahi and Abdulrahman, 2021; Singh et al., 2022; Sani et al., 2022). In the Sudano-Sahelian region, Mohamed et al. (2022) assessed the impact of Jatropha curcas' plants on soil nutrient enhancement of the soils in the area, but assessing the potential of the plant in improving the fertility status of the soils, particularly marginal ones, was absent. Therefore, this research aimed to assess the influence of Jatropha curcas on the soil fertility of Sudanese Savannah Alfisols. The specific objectives are;

i) To assess soil physical and chemical fertility parameters before and after planting Jatropha curcas
ii) To evaluate the effectiveness of Jatropha curcas on improving soil fertility parameters improvement.

2.0 Materials and methods

2.1 Study area and Experimental site description

The experiment was carried out in the university nursery unit of the Forestry and Wild Life Management Department, Aliko Dangote University of Science and Technology, Wudil. The geographical location of the site was between N11˚48'18" latitude and E8˚51'40'' longitude and about 37.5m above sea level with annual rainfall and temperature ranging from 850mm to 870mm and 26ºC and 33ºC respectively. The relative humidity of the region was always low and ranged from 40% to 51.3% (Olofin et al., 2008)

2.2 Collection, preparation of soil samples, and experimental duration

A total of 12 samples and 3 controls were collected and used in the nursery experiment. The sampled soils were measured at the pre- and post-Jatropha planting periods with seeds and cuttings in the experimental pots, respectively. Furthermore, the experimental soils were thoroughly mixed with the quantity of organic fertilizer (in the case of organic amended treatments) in a ratio of 2:1 and well-watered prior to sowing to assess the impact of organic amendment on the performance of jatropha in soil fertility improvement.

The experiment lasted for good three months from March 15 to June 15, 2023, during which the Jatropha plant had attained its growth juvenility stage capable of reclaiming the soils (Ofelia et al., 2013). The plant was watered twice daily and then reduced to once when the plant exceeded two months of growth. Hand weeding was also performed, as well as proper supervision of the experimental site during the whole period of the experiment.

2.3 Experimental treatment and design

The treatments were Jatropha plant seeds free of organic matter amendment (SF) T1, cuttings free of organic matter amendment (CF) T2, seed with organic matter amendment (SO) T3, and cutting with organic matter amendment (CO) T4, tested on free amended and organic amended marginal soils. Here, TO is the control.

The experimental pots were labeled according to their composition, and each treatment was replicated three times with a total of 12 (12) samples and 3 control soils, all arranged in a completely randomized design (CRD).

2.4 Laboratory analyses

The physical and chemical fertility parameters of the soils were analyzed at pre- and post-planting Jatropha using standard laboratory procedures; Soil pH and EC were determined using pH and conductivity meter, respectively. Cation exchange capacity (CEC) was determined using neutral pH_7 in NH_4OAC saturation method as described by Anderson and Ingram (1993). Organic carbon was determined by the dichromate oxidation method as detailed by Nelson and Sommers (1982), and mechanical analysis was by standard hydrometer method as outlined by Gee and Bauder (1986). Total Phosphorus was determined by acid digestion as outlined by Murphy and Relay (1962), Total Nitrogen content was determined using the micro-Kjeldhal technique as described by Bremner (1996), and exchangeable bases of Na and K were determined using a flame photometer; Mg and Ca were determined using an atomic absorption spectrophotometer.

2.5 Statistical analysis

To assess the level of soil fertility parameters and their corresponding differences, mean values of the parameter concentrations were subjected to analysis of variance (ANOVA) using R statistical software. The treatment means were separated using Least Significant Difference (LSD) at 5% probability level.

3.0 Results and Discussion

3.1 Experimental soil fertility during the pre-planting Jatropha period

Table 1 shows the overall mean values of the experimental soil properties in the study area before the planting of Jatropha. The recorded pH values were neutral (Msanya, 2012; Sani et al., 2021), electrical conductivity, organic carbon, phosphorous, nitrogen, exchangeable cations, and cation exchange capacity were of low concentration and belonged to low fertility classes (Esu, 1991; Sani et al., 2022). The low nutrient status depicted at the pre-planting period indicates the soil characteristics of degraded marginally nutrient-scarce soils that are vulnerable to erosion (Sani et al., 2022) and not compliant with quality standards of agricultural soils.

3.2 Effects of jatropha curcas on soil fertility

3.2.1 Soil pH

Soil pH is an important index of soil fertility and affects the movement and distribution of nutrients in the soil matrix. For instance, under low soil pH conditions, the nutrients most needed by crops are not readily available for absorption but the undesirable ones become more accessible and can reach levels of toxicity (Sani et al., 2020), which can affect the growth of crops. The soil pH results during the post-Jatropha planting period are shown in Table 1. The pH range was between 6.32 and 7.02 in all treatments, with significant differences recorded ($P<0.05$) between the pre- and post Jatropha planting periods and the soil treatments (Tables 1 and 2).

The pH values of the experimental soils at the pre-Jatropha planting period were 6.77; however, at the post-planting period, the values for all the treatments decreased, except for the SO treatment (Table 1). This reduced pH values among the treatments could be attributed to the Jatropha plant roots ability to release exudates in the soil

Table 1: Overall mean values of soil fertility parameters of experimental soils at both the pre- and post-jatropha planting periods

Marginal Soil Properties during the Pre-*Jatropha* planting period		Marginal Soil Properties during the Post-*Jatropha* planting period			
	Experimental Soil Treatment				
Soil Properties	Values	SF	CF	SO	CO
pH(-)	6.77	6.32	6.38	7.02	6.34
EC (dS/m)	0.05	0.09	0.14	0.14	0.15
OC (%)	0.36	0.42	0.38	1.14	0.90
P (mg/kg)	6.33	13.91	8.25	60.3	70.59
N (%)	0.14	0.28	0.14	0.25	0.18
K (cmol/kg)	0.14	0.22	0.18	0.11	0.36
Na (cmol/kg)	0.13	0.23	0.18	0.12	0.34
Ca (cmol/kg)	0.14	0.19	0.16	0.11	0.27
Mg (cmol/kg)	0.14	0.24	0.18	0.13	0.22
CEC (cmol/kg)	6.54	3. 81	6. 68	6. 18	5.66

Note, SF, *Jatropha* seeds without any organic amendment, CF, *Jatropha* cuttings without any organic amendment, SO, *Jatropha* seeds with organic amendment and CO, cuttings with organic amendments, pH is potential hydrogen, EC is electrical conductivity, OC is organic carbon, P is phosphorous, N is nitrogen, K is potassium, Na is sodium, Ca is calcium, Mg is magnesium, CEC is cation exchange capacity, dS/m, decisiemens per meter, %, percentage, Mg/kg is milligram per kilogram, Cmol/kg is centile per kilogram and g/cm^3 is gram per centi-meter cube

rhizosphere that might have caused the reduction in the pH values observed (Edris, 2015; Daliya et al., 2020). Conversely, the increased pH values recorded in the SO treatment could be ascribed as a result of mineralization of organic matter leading to release of exchangeable cations, which might have increased the recorded pH values indicating the impact of Jatropha plants on the pH of the treatments and was confirmed elsewhere (Ano and Agwu, 2005). Nonetheless, despite significant pH variation at pre- and post Jatropha planting periods between the soil treatments, the pH range is within the compliance limit of fertile and qualitative agricultural soils (FAO, 2020).

3.2.2 Electrical Conductivity (EC)

EC is a measure of the ability of a solution to carry an electric current or the concentration of soluble salts in the sample at any specific temperature. The EC values recorded at both the pre- and post-jatropha planting periods (Table 1) were below 4ds/m, a value considered acceptable for most crops (FAO, 1993). The results also indicated that Jatropha increased EC values in all treatments (Table 1) despite being low in concentration. Moreover, the differences in the EC concentration between the treatments in both the pre- and post-planting Jatropha periods were significant ($P<0.05$) according to (Table 2), with SF recording the lowest values. The plausible reason for this difference could be attributed to an increase in the number of particles released from the plant.

roots and accumulation of exchangeable bases from decomposition of organic matter in the rhizosphere vicinity leading to the variation recorded in the increased EC values (Table 1) in the affected treatments, as reported elsewhere (Habtamu, 2011; Sisay et al., 2016).

3.2.3 Organic carbon (OC)

Soil OC is critical for the sustenance of plant growth. It is the carbon stored in soil organic matter content is the primary source of fertility in soil (Jobbágy and Jackson, 2000). Overall, Table 2 shows an increase in OC in all the treatments with SO and CF at the post Jatropha planting period, with the highest and lowest values, respectively. In addition, the increase was highly significant (P<0.05). This high increase in SO treatment could be attributed due to the fact that, decomposition of additional application of organic matter to the treatments, Jatropha leaf degradation, and accumulation of plant root exudates, which could have triggered the concentration of OC (Sisay et al. 2016), which were absent in the other treatments.

3.2.4 Nutrients (NPK)

N, P, and K are the most essential nutrients and indices for soil fertility improvement that support plant growth, development, and reproduction (Abdullahi et al., 2021; Sani et al., 2022). According to Table 1, The P and K nutrients showed an increasing trend, with CO recording the highest values, compared with the other treatments at post Jatropha planting period in comparison with the pre-planting period. However, N recorded the highest values in the SF. Moreover, the differences in the higher values recorded were highly significant (P<0.05) as shown in Table 2.

Table 2: Statistical differences in the soil quality parameters at the post jatropha planting period in the study area

Soil Parameters	SF	CF	SO	CO	O
pH	6.32^{d}	6.38^{b}	7.02^{a}	6.34^{cd}	6.35^{c}
EC	0.09^{b}	0.14^{a}	0.14^{a}	0.15^{a}	0.16^{a}
OC	0.42^{c}	0.38^{d}	1.14^{a}	0.90^{e}	0.64^{b}
P	13.91^{d}	8.25^{e}	60.3^{b}	70.59^{a}	23.5^{c}
N	0.28^{a}	0.14^{d}	0.25^{b}	0.18^{c}	0.11^{e}
K	0.22^{b}	0.18^{c}	0.11^{d}	0.36^{a}	0.21^{b}
Na	0.23^{b}	0.18^{c}	0.12^{d}	0.34^{a}	0.19^{c}
Ca	0.19^{b}	0.16^{c}	0.11^{d}	0.27^{a}	0.13^{d}
Mg	0.24^{a}	0.18^{c}	0.13^{d}	0.22^{b}	0.18^{c}
CEC	6.54^{b}	3.81^{e}	6.68^{a}	6.18^{c}	5.66^{d}

Note: SF, *Jatropha* seeds without organic amendment; CF, *Jatropha* cuttings without organic amendment; SO, *Jatropha* seeds with organic amendment and CO, cuttings with organic amendments; pH is potential hydrogen; EC is electrical conductivity; OC is organic carbon; P is phosphorous; N is nitrogen; K is potassium; Na is sodium; Ca is calcium; Mg is magnesium; CEC is cation exchange capacity; and MWD is mean weight diameter.

The plausible reason for this increase and its variation among the treatments could be attributed to differences in soil microorganisms and their activities induced by the conducive microclimate provided by the Jatropha plant and organic matter accumulation from the applied manure, decayed litter and roots exudates in the rhizosphere with respect to P and K nutrients, and the mobility nature of N in soil could have led to the differences and variations of values observed in the different treatments (Tables 1 and 2) and was in conformity with data reported elsewhere (Daliya et al., 2020; Sani et al., 2022).

3.2.5 Exchangeable Bases (Na, Ca and Mg)

The result of exchangeable Na, Ca, and Mg showed variability in the increasing trend of their concentration in the experimental treatments (Table 1) in the post Jatropha planting period in comparison to pre-planting one, with

Table 3: Overall mean values of the soil textural parameters of the Experimental Soils at both the pre- and post-jatropha planting periods

Textural Soil Properties during the Pre-*Jatropha* planting period		Textural Soil Properties during the Post-*Jatropha* planting period			
	Experimental Soil Treatment				
Soil Texture Properties	Values	SF	CF	SO	CO
Sand	76.56	64.4	66.4	70.56	74.4
Silt	18.56	26.56	22.56	20.44	18.56
Clay	4.88	9.04	11.04	9.00	7.04
Textural Class	Loamy Sand	Sandy Loam	Sandy Loam	Loamy Sand	Loamy Sand

Note: SF, *Jatropha* seeds without organic amendment; CF, *Jatropha* cuttings without organic amendment; SO, *jatropha cuttings* with organic amendment; CO, cuttings with organic amendment

Na and Ca recording highest values in CO while lowest values were recorded in SO and Control, and the difference was statistically significant (P<0.05) as depicted in the statistical table (Table 2). Contrastingly, the SF treatment recorded the highest concentration of exchangeable Mg compared to other treatments with high statistical difference (P<0.05; Table 2). This finding is surprising considering the reported increase in their concentration in the literature (Habtamu et al., 2011). However, this contradiction could be attributed to the differences in temperature of the soil rhizosphere, nature, and population density of the microorganisms in the study of the reported literature and that of the current study, which were involved in the process of mineralizing the organic matter and Jatropha root released exudates that subsequently pump and increase the concentration of nutrients, including the exchangeable bases (Pandey et al., 2012; Sani et al., 2022).

3.2.6 Cation exchange capacity (CEC)

CEC is an index of fertility that describes the potential of soil to supply nutrient cations to soil solutions for plant uptake (Sonon et al., 2014). The CEC results (Table 1) indicated an increase in its concentration in all treatments, excluding CF, at the post-Jatropha planting period in comparison with the pre-planting one. The SO treatment recorded the highest values compared to other ones while CF recorded lowest values, indicating reduction of CEC in that treatment (Table 1), and the differences in the mean values were significant (P<0.05) statistically (Table 2).

This reduction could be attributed to the combined effect of the lack of organic matter and the type of microorganisms involved in the decomposition of the organic matter, which increased the CEC concentration, leading to the observed recorded lowest values in the CF treatment. Conversely, the nature, selectivity, and availability of the microorganisms in the SF treatment plus the release of the Jatropha plant exudates, which increase organic matter concentration (Singh et al., 2022), could be the reason behind the high CEC concentration recorded in the SF treatment. Moreover, the application of organic manure and the decomposition of plant root exudates could have triggered the CEC concentration observed in the SO and CO treatments, respectively, as confirmed elsewhere (Velayutham, 2000).

3.3 Textural classes of the experimental soil

Soil texture refers to the percentage or relative proportion of sand, silt, and clay present in a soil and is a critical physical parameter that enhances water permeability, porosity, aeration, and water-holding capacity (FAO, 2006), with a positive impact on soil fertility, plant growth, and overall productivity.

Table 3 depicts the results of the soil texture of the marginal soils at the pre- and post-Jatropha planting periods in the SF, CF, SO, and CO treatments, respectively, with increasing and decreasing trends in the concentration of the soil texture parameters. Silt and clay particles showed an increasing trend from the pre-Jatropha planting period and post planting one across all treatments, while sand fractions decreased in that order and dominated silt and clay particles, indicating the impact of jatropha plants on textural particles. The plausible reason for the decreasing and increasing trend of sand, silt, and clay fractions, respectively, could be attributed to the lack of organic amendments in the degraded soils at the pre-Jatropha planting period, leading to the observed high sand particles recorded when compared to silt and clay in all the treatments, which are characteristic nature of savannah alfisols (Sani et al., 2022). However, the recorded values of silt and clay increased overtime during the post Jatropha planting period due to the additions of organic and inorganic materials released from the decomposition of the released Jatropha plant root exudates and manure additions, resulting in an observed increase in their recorded values (Agbodi et al., 2013; Sani et al., 2022) (Table 3). Moreover, Jatropha plant roots have been reported to anchor soils with a substantial and consistent root system architecture that serves as a nutrient pump capable of replenishing soil lost nutrients. Subsequently, leading to the rehabilitation of the degraded soils, improving their structure and enhancing their quality, fertility, and productivity (Divakara et al., 2009; Pandey et al., 2012).

4.0 Conclusion

The main objective of this research was to evaluate the influence of Jatropha plant on soil fertility improvement of degraded Sudan Savannah alfisol. Findings indicated that the pH of the soils was within the range of 6.77-7.02 and their texture was sandy loam and loamy sand, respectively. Furthermore, the results indicated that plant cuttings and seeds with organic amendments (CO and SO) improved major soil fertility parameters; nitrogen content N, exchangeable bases (EB), organic carbon (OC), phosphorus (P), and cation exchange capacity (CEC) higher than the plant cuttings and seeds without amendments at the post Jatropha planting period compared with pre-planting ones. Comparably, cuttings with organic amendment (CO) improved soil fertility higher than the latter and other treatments during the post Jatropha planting period. Moreover, statistical analyses indicated that both physical and chemical soil fertility parameters showed statistically significant variation ($P<0.05$) with Jatropha planting in SO and CO treatments with major soil fertility parameters; OC, P, EB, and CEC. However, very little soil property variation was observed in the control soil samples over the study period, possibly due to the soil being left fallow during the research period.

Overall, the research indicates the influence of the Jatropha plant transition on degraded soils from a low nutrient status to fertility enrichment on soil physicochemical fertility properties. The study revealed that over a period of 3 months, the fertility status of the degraded soils positively increased from low to high after planting the Jatropha plant.

Farmers will benefit from the findings of this research by planting Jatropha in their marginal lands to restore lost nutrients and improve soil fertility and productivity. Moreover, they can grow their crops alongside jatropha plants in a hedgerow intercropping to derive the maximum benefits of soil nutrient enrichment for better agricultural yield, as findings confirmed that the plant had no negative impact on food crops.

Regarding recommendations, the duration of the experiment should be extended beyond three months to fully assess the overall impact of plant potential on the fertility improvement of degraded soils. Furthermore, the government should create awareness and encourage farmers to deploy these research findings and grow more small economic trees that mature rapidly between one to three years like Jatropha in their farms, particularly in the degraded soils of semiarid lands of Nigeria to provide lost quality and fertility of the soils and improve soil nutrient management for sustainable agricultural production.

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