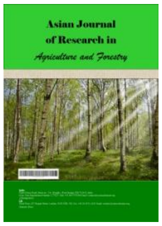

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Utilization of *Parkia biglobosa* Leaves as Green Manure for the Fertilization of Maize (*Zea mays L.*) in Southern Nigeria

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Authors' contributions

This research was carried out in collaboration among all the authors. Authors KOO and OO designed, planned and supervised the experiment, and wrote the manuscript. Author CM managed the work and carried out the analysis. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To investigate the use of *Parkia biglobosa* leaves as a source of organic nutrients for maize production.
Place and Duration of Study: The field experiment was carried out at the research field of the Federal Ministry of Agriculture and Rural Development, Lagos State Field Office, Nigeria during the early planting season (March/April) of 2018.
Methodology: A field research was carried out to compare the growth and yield of maize when *Parkia biglobosa* leaves and inorganic fertilizer were used as nutrients sources. Four factorial treatments combinations of *Parkia biglobosa* leaves, NPK fertilizer, combined *Parkia biglobosa* leaves and NPK fertilizer, and a control experiment was ordered in a Randomized Complete Block Design with four replicates. The plants height, number of leaves and surface areas were recorded at 3, 6 and 9 weeks after planting while the maize yields were considered at the end of the experiment.

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Results: The study showed that the treatment with the combination of *Parkia biglobosa* leaves and inorganic fertilizer produced the highest indexes of plant tallness, foliage number and surface areas. Maize yields of 2816.66, 2700, 2316.66 and 1566.66 kg/ha were recorded from treatments with *Parkia biglobosa* leaves and inorganic fertilizer combination, inorganic fertilizer, *Parkia biglobosa* leaves and the control experiment, respectively.
Conclusion: These results reflected that the incorporated effect of *Parkia biglobosa* leaves and inorganic fertilizer at the rate of 50:50 gives the best maize growth and yield index.

Keywords: Parkia biglobosa; nutrients; soil fertility; maize; growth; yield.

1. INTRODUCTION

Sustainable agriculture is the agricultural system that makes the best use of the available resources without destruction of in-situ resources [1]. It ensures proper and optimum utilization of the available resources to build a practicable business pattern that is efficient in conserving and enhancing the assets achievable in the business, be it the soil, water, human capital, etc. According to Starik [2], sustainability is the capacity to harvest the present needs without jeopardizing the future needs.

It is certain that improvement in the soil physical conditions will increase the crop growth potential, but it is not easy to arrive at this affinity quantitatively and to ascertain the degree of amendment that is required to achieve significant increase in crop production. Nevertheless, in order to supply manure to satisfy the nutrients required by plants, the knowledge of the quantity of nutrients available in the soil and the one that will be released from manure sources is required [3]. The fertility of the soil and crop varieties are regarded as the principal factors that determines the success of crop production [4]. The percentage of organic matter available in the soil can be increased with the addition of green manure as it will improve aeration, water holding capacity and other soil properties. Green leaves from plants with high foliage are beneficial to proper management of the soil. Some of the benefits that are associated with green manure include the addition of nitrogen, conservation and availability of nutrients, improvement in physical soil condition and control of erosion, diseases and weed [5]. Regular and continuous supply of nutrients especially nitrogen is required by maize at every stage of its growth, right from planting to seed filling stage. Prudent use of organic manure like compost or farm yard manure at the rate of 15 – 20 t/ha about 20 days before seed planting and green manuring or application of oil cakes at the rate of 6 – 10 t/ha have been reported by Vasilakolou et al., [6] as the perfect combination to improve crop yields especially grain crops. Decomposition of organic manures ensure re-introduction of nutrients that are already present in the soil, such as nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg) and sulphur (S) which are mostly essential for maize production.

Aye and Mungatana [7] opined that increasing the yield is one of the important ways to completely address the food deficit problems that has led to increase in food prices globally. One of the ways for increasing maize production is to ensure its production with minimum inputs through sustainable management techniques [5]. Recently, the use of fertilizers for cereals especially maize, a high nutrient demanding crop, has led to substantial increase in cost of cultivation. However sometimes, the present rates of application are low due to the cost and also availability of chemical fertilizers. Fertilizer application in tropical agriculture has the ability to vividly improve yield because of the good weathered soils and the circumscribed backlogs of nutrients [8]. Nevertheless, application of fertilizers at recommended quantity and quality based on the soil test results is not often managed which always leads to misuse and other economic losses associated with it [9], and causes environmental hazards [10].

Maize is usually the first crop to harvest and use as food in the early part of the year when there is hunger in Nigeria because of its shorter life cycle [11]. According to [12], 1099.6 million metric tons is the global maize production in 2017/2018 and United States of America was the principal producer with about 394.43 million metric tons (35.87%) of the total production while about 5% of the production was produced in Africa where South Africa was the principal African producer with about 14.40 million metric tons (1.31%) and followed by Nigeria 11.66 million metric tons (1.06%). All available lands in Nigeria support maize production but a well-drained fertile loamy soil will give better results. Being a very important basic food source for millions of Nigeria and inhabitants of West Africa countries, 43% of maize produced in West Africa is from Nigeria [13,14,15]. Despite the abundance of maize in Nigeria, about 80% serves as food for both man and animals while the rest 20% is being utilized by industries for the production of ethanol, oil, cereal, alkaline, high fructose and corn sweetener. However, the challenges in maize production can be linked to the fact that about 90% of the farmers are peasant farmers with old farming methods, scurvy capitalization and miserable yield per hectare [16]. In order for Nigeria to be self-sufficient in maize, there is need to improve its production such that there will be excess for export after local consumption. Ado et al*.,* [17] concluded that sustainable maize production is attainable by adopting improved production technologies, development of innovative methods of processed maize utilization for the urban and village level consumption as well as provision of credit facilities to small holders.

For improved growth and yield, there is need to supply maize plants with sufficient nutrients especially nitrogen, phosphorous and potassium. The amount of these nutrients required especially nitrogen depends on the type of vegetation on the farm land before clearing, organic matter content present in the soil, tillage method adopted and intensity of light [18]. Sulphur, magnesium and zinc are some of the essential micronutrients needed for maize growth especially in the savanna regions and grasslands where maize is grown under continuous cropping. Applying the correct form of fertilizer which has the required mixture of the elements will satisfy the nutrients required by the crop. Adequate use of fertilizer during sowing furnishes the seedlings with the main nutrients needed in the early stages of growth while inadequacy or excessive application of fertilizer may lead to crop failure and nutrient imbalance.

Likewise, the awareness on the need to grow non-timber forest products (NTFPs) is gaining momentum in the past decades because of their significance in the economy of many forest-dependent households and their influence as major biomass-yielding plants in the economies of numerous developing countries. One common example of the non-timber forest products is *Parkia biglobosa*, which has woody characteristic features that can be used as energy source either as fuel wood or charcoal and some other important products that are not timber [19]. There is considerable interest regarding the full utilization of this resource while at the same time keeping biodiversity and guarantee sustainability. Understanding the potential uses of this product and their conversion and commercialization will encourage their promotion. *Parkia biglobosa* (sub-family Mimosoideae and family Fabaceae) commonly called African locust bean tree is a leguminous perennial tree that can be found from the savannah part of West African to the Southern border of the Sahel zone areas [20]. This can be found in some African countries which include Nigeria, Benin Republic, Ghana, Central Africa Republic, Sudan, Cote d'ivoire, Senegal, Burkina Faso, Sierra Lone, Uganda, Gambia, Mali, Togo, Guinea Bissau and Niger Republic [21]. It flourishes well in the Southern part of Nigeria where rainfall is about 1500 mm and has the ability to resist drought because of its deep tap root system and ability to restrain evapotranspiration [22].

Parkia biglobosa has diverse functional utilizations and is very crucial because of its products [23]. The principal products are food and other parts of the tree are beneficial in one way or the other. Some of the products from this tree are: food, animal folder, medicine, fire wood, glazes, soil improvement and charcoal. Because of the seasonality of its fruit maturation, the food products from *Parkia biglobosa* are very important. People usually roast the premature green whole pods and eat around February/March and between March and April during the period that is tagged as 'hunger season' when other foods are not plentiful. In West Africa, seeds are processed into a condiment called iru or dawadawa, which is a very good source of protein in Nigeria and Ghana. It is also an important part of commerce in some villages and towns [24,25]. Domestic livestock like cattle, sheep and goat can feed on the whole pods and the premature seedlings are more edible and nutritious to the livestock. One of the important characteristics of this tree is that majority of its leaves are chiefly green all through the dry season and the branches are pruned and served as fodder. The wood is comparatively hard and solid, very easy to work on with either by hand or power tools; easy to glue and nail; paint and varnishes well; it is mostly used as a light structural timber in crates, furniture, boxes, agricultural implements, barrels, bowls, mortars and pestles, planks and carvings [26].

One of the major problems faced by maize farmers is low productivity arising from poor soil fertility coupled with the substantial high cost of inorganic fertilizer and its negative effects on the environment. Therefore, there is need to identify some green manure like *Parkia biglobosa* leaves and other agricultural wastes that are readily available and can add nutrients to the soil and bring about soil improvement which in turn increase the production of maize at relatively low cost and environmental friendly. Although there are several literatures on the use of agricultural wastes and biomass as green manure, the use of *Parkia biglobosa* leaves, which is the focus of this study, has not been explored as an organic fertilizer rich in relative nutrients suitable for maize production. This study will serve as an opener to assessment and consideration of the fertilization effect of *Parkia biglobosa* leaves on a specific crop and the subsequent utilization on other profitable crops within and without Africa.

2. MATERIALS AND METHODS

The field experiment was carried out at the Research field of the Nigeria Federal Ministry of Agriculture and Rural Development, Lagos state field office. The area is situated in the tropical rain forest zone of Nigeria and the upper part is derived or guinea savanna vegetation. The state lies on coordinate 6°35′ N and 3°45′ E, altitude 39 m above the sea level and bimodal rainfall. The state has a tropical climate; the summers are much rainier than the winter with average minimum temperature of 27°C and average annual rainfall of 1,693 mm [27]. The minimum rainfall was recorded in December while the highest precipitation was recorded in June. The experiment was carried out in the year 2018 during the early planting (March/April) season which represent the common planting period for early maize in this agro-ecology zone.

2.1 Experimental Design

The treatments were replicated four times in a Randomized Complete Block Design (RCBD). The treatments consist of *Parkia biglobosa* leaves applied as green manure at the rate of 55,556 kg/ha, inorganic fertilizer using NPK fertilizer at the rate of 60:40:40, combine application of 50% green manure using *Parkia biglobosa* leaves and 50% inorganic fertilizer using NPK at the treatment rate of 60:40:40 and the control experiment. The plots were labeled T_1 – T_4 as shown in Table 1.

2.2 Experimental Set-up

Soil sample was collected in all parts of the experimental field at 30 cm depth, bulked; air dried and was analyzed in the laboratory for the physicochemical characteristics prior to planting and after harvesting. The site was cleared, ploughed, harrowed and ridged and the maize seed was procured from Lagos State Agricultural Inputs Supply Services center (LAISS) in Oko-Oba, Agege. The blocks were arranged from north to south having 4 plots each and a surface area of each plot is 2.7 m^2 (1.8 m x 1.5 m) detached by 1m alley and the seeds were sown at a space of 90 cm x 30 cm, weeding was carried-out manually at weeks 3 and 6 after planting.

2.2.1 Treatments Application

i. 55,556 kg/ha of *Parkia biglobosa* leaves (organic manure) was ploughed into the soil in the plot (2.70 m^2) and irrigated for 21 days before planting.

ii. 2,778 kg/ha of inorganic fertilizer NPK (15:15:15) was used at recommended rate of 60 kg/ha (Nitrogen), 40 kg/ha (Phosphorous) and 40 kg/ha (Potassium) on another plot (2.70 m^2).

iii. 7.5 kg of *Parkia biglobosa* leaves was also ploughed into the soil and irrigated for 21 days before planting and 0.3 kg/plot of inorganic fertilizer NPK 15:15:15 was later used three (3) weeks after planting on another plot that measured (2.70 m^2).

iv. Another plot of 2.70 m^2 was left without adding any manure to serve as the control experiment.

Table 1. Grouping for different nutrient sources

Treatments	Nutrients Sources
T_1	Leaves of *Parkia biglobosa* (55,556 kg/ha)
T_2	NPK inorganic fertilizer (222.2 kg/ha)
T_3	NPK inorganic fertilizer (111 .1 kg/ha) + *Parkia biglobosa* leaves (27,778 kg/ha)
T_4	No form of manure is added

2.3 Data Collection

The assessment of growth parameters was done randomly and ten (10) maize stands were identified and labeled on each plot as samples. The plant heights were measured from the tagged plants from the ground level to the tip of the plant with the use of meter rule at weeks 3, 6 and 9 while the total number of the leaves on each of the tagged plant per plot were also enumerated and recorded in the same weeks 3, 6 and 9. To determine the leaf area index, the length and breadth of the identified plants were measured at 3, 6 and 9 weeks and the number of cobs produced by each of the plant was recorded at the physiological maturity stage. The number of seeds per cob was ascertained when the number of seeds that each of the cobs from the selected plants produced were counted, and these seeds were weighed with weighing scale to get the results of the weight of cobs per plant.

2.4 Data Analysis

The data accrued was exposed to Analysis of variance (ANOVA) to determine whether the observed variations amongst treatments means were significant at $p \leq 0.05$. The mean were then sorted using Duncan Multiple Range Tests (DMRT).

3. RESULTS AND DISCUSSION

3.1 Physicochemical Properties of the Soil before and after Planting

The result of the soil sample before planting and after harvesting for the each treatment is as shown in Table 2. The results show that there are other micronutrients, apart from NPK, that were added to the soil by the *Parkia biglobosa* leaves which are not in NPK fertilizer. The results also showed that these micronutrients are in excess and remain available in the soil after harvesting pending another planting season. The availability of these micronutrients like Ca and Mg can be linked to the reason why T_3 produced the best results. It was also shown from these results that *Parkia biglobosa* has high percentage of macronutrients that is needed to boost maize production.

3.2 Number of Leaves

The results of the average number of leaves from the treatments are shown in Table 3. The results show that there was no significance difference ($p \leq 0.05$) in the number of leaves at 3 WAP, 6 WAP and 9 WAP. However, at 3 WAP, T_3 had the most average number of leaves (10.00) and T_4 had the average lowest number of leaves (8.31). At 6 WAP, T_1 had the average most number of leaves (13.5) and T_4 had the average lowest number of leaves (10.88). At 9 WAP, T_2 had the average highest number of leaves (13.62) and T_4 had the average lowest number of leaves (12.69). At $p \leq 0.05$, the non-significant numbers of leaves might be due to the effect of the *Parkia biglobosa* leaves which add nutrient value from decomposed leaves buried in the soil before planting. This result is in accordance with findings of Iyang, [28] who concluded that the application of NPK fertilizer at 180 – 190 kg/ha supplied the required nutrient for vigorous growth, production of larger leaves, thick and good canopies for efficient light interception. The number of leaves recorded for all the treatments is higher than what Thorat, [29] reported when different sweet corn hybrids were treated with various fertilizer levels.

3.3 Plant Height

The results in Table 4 revealed that there was significant difference at $p \leq 0.05$ in plant height at 6 WAP and 9 WAP. However, there was no noticeable significant difference in plant height at 3 WAP.

Table 2. Physicochemical Properties of the Soil before and after Planting

Properties	Before Planting	T_1	T_2	T_3	T_4
Clay (%)	16.00	18.00	17.00	24.00	13.00
Silt (%)	16.00	19.00	16.67	19.00	12.00
Sand (%)	68.00	58.00	67.52	54.00	73.00
Organic Carbon (%)	0.50	0.53	0.49	0.82	0.49
Total Nitrogen (%)	0.043	0.049	0.051	0.072	0.027
Available Phosphorous (mg/Kg)	8.75	9.23	8.92	13.22	5.35
Ca (C mol/kg)	4.00	4.36	3.97	4.02	3.96
Mg (C mol/kg)	1.16	1.37	1.16	1.53	1.14

Table 3. Effects of Different Treatments on the Number of Maize Leaves

Treatments	3 WAP	6 WAP	9 WAP
T_1	8.29	13.56	13.06
T_2	9.13	13.06	13.62
T_3	10.00	13.31	13.50
T_4	8.31	10.88	12.69
SE ±	0.74	0.62	0.55

**Means followed by the same letter within a sampling stage is not statistically significant at 5% level of probability. SE ± = Standard error plus or minus, WAP = Weeks after planting*

Table 4. Effects of different treatments on the plant height

Treatments	3 WAP	6 WAP	9 WAP
T_1	55.14	181.45a	142.93d
T_2	48.52	174.35c	219.00b
T_3	49.52	178.23b	225.00a
T_4	38.24	110.31d	181.25c
SE ±	5.19	6.58	7.48

**Means followed by the same letter within a sampling stage is not statistically significant at 5% level of probability. SE ± = Standard error plus or minus, WAP = Weeks after planting*

At 3 WAP, T_1 had the highest value for plant height (55.14 cm) and T_4 had the lowest value (38.24 cm). The highest value of T_1 at 3 WAP might be due to the fact that the *Parkia biglobosa* leaves that were applied 21 days prior to planting had started decomposing and this resulted in the release of the nutrients to the soil. At 6 WAP, T_1 again had the highest value of plant height (181.45 cm) and T_4 had the lowest height (110.31). At 9 WAP, T_3 had the highest value of plant height (225.0 cm) and T_4 again produced the lowest height (181.25 cm). The highest height recorded in T_3 might be due to the fact that the supply of nutrient by the *Parkia biglobosa* leaves was slow and steady, which was also complemented by the NPK fertilizer. The results obtained agreed with the findings of Watts et al., [30] which affirms that burying manures into the soil will instantly lead to increase in copiousness of soil microorganisms that supports the decay of the fresh materials which significantly increase the plant height of maize crop.

3.4 Leaf Area

The result of leaf area shows that there was noticeable significant difference in the leaf area (Table 5) at 3 WAP, 6 WAP and 9 WAP. At 3 WAP, T_1 had the highest leaf area (587.23 cm^2) and T_4 had the lowest value (362.08 cm^2). At 6 WAP, T_2 had the highest value of leaf area (498.22 cm^2) and T_4 had the lowest value (349.55 cm^2). At 9 WAP, T_3 had the highest value of leaf area (445.72 cm^2) and T_4 had the lowest value of leaf area (312.40). The result obtained agreed with the reports of Sharply et al., [31] which state that incorporating cowpea into the soil before planting significantly leads to soil improvement and soil protection. The inclusion of *Parkia biglobosa* leaves into the soil caused the length and breadth of the leaf of maize plant to increase.

Table 5. Effects of Different Treatments on the Leaf Surface Area

Treatments	3 WAP	6 WAP	9 WAP
T_1	587.21a	482.22c	406.19c
T_2	495.47c	498.22a	443.22b
T_3	505.88b	486.63b	445.72a
T_4	362.08d	349.55d	312.40d
SE ±	15.41	21.79	5.91

**Means followed by the same letter within a sampling stage is not statistically significant at 5% level of probability. SE ± = Standard error plus or minus, WAP = Weeks after planting*

Table 6. Effects of different treatments on the number of cobs, number of seeds per cob and weight of cobs

Treatments	Number of Cobs	Number of Seeds per Cob	Weight of Cobs (kg/ha)
T_1	1.12	417.12c	2316.66
T_2	1.06	530.56a	2700.00
T_3	1.12	518.75b	2816.6
T_4	1.00	331.98d	1566.66
SE ±	0.07	28.48	0.05

Means followed by the same letter within a sampling stage is not statistically significant at 5% level of probability. SE ± = Standard error plus or minus

3.5 Yield and Yield Parameters

The results in Table 6 show that there was no significant difference in the number of cobs per stand. The results also revealed that there was no significant difference in the number of seeds per cob. T_2 (530.56) and T_3 (518.75) had the highest number of seeds per cob and T_4 had the least number (331.98). Considering the weight of the yield, the results show that there was no noticeable significant difference. T_3 had the highest value of cob weight (2816.66 kg/ha) and T_4 had the lowest value of cob weight (1,566.66 kg/ha).

The results also indicate that the combination of *Parkia biglobosa* leaves and NPK fertilizer consistently had good influence on weight of cob and number of seed per cob. On the other hand, this means that the total yield from the plot area of 2.70 m^2 was about 6,255 kg while the total yield obtained from T_2 was 0.729 kg and T_3 gave a yield of about 0.761 kg. The highest yield in T_3 may be because of the availability of other micronutrients that are available in *Parkia biglobosa* leaves which complement the macronutrients present for improvement of soil aeration and organic matter as reported by Maobe, [32]. The yield result was higher than 1,528 kg/ha maize yield recorded by World Bank, [33] in Nigeria, and 1,400 kg/ha yield recorded by Ogundari, [34]. IITA, [35] projected 2,000 – 3,000 kg/ha for open pollinated maize in southern Nigeria and all the treatments except T_4 falls within this range. The results recorded here corroborate what was reported by Fabunmi and Balogun, [36] that green manure was noted to improve maize when cowpea green manure was used in another experiment. Results of this study are in agreement with what [37] reported that the incorporation of green manure in temperate regions improved the production and reduced the inorganic fertilizer input, while [38] concluded that green legume incorporation can improve the maize grain yield significantly. Onyango et al., [39] earlier reported that application of green manure legumes in Kenya has shown a great potential in sustaining maize yields for resource-poor farmers. Therefore, utilization of organic materials with low Carbon to Nitrogen (C:N) ratio like green manure contemporized nutrients supply to the plant need for short cycle crops with high nutrient demand like maize [40,41].

4. CONCLUSION

The combination of *Parkia biglobosa* leaves and NPK fertilizer consistently performed better when compared with other treatment in most of the growth parameters considered. The combination of the *Parkia biglobosa* leaves and NPK fertilizer had the highest weight of cob and highest number of seed per cob. This showed that *Parkia biglobosa* leaves contain some nutrients that improved the growth and yield of maize crop and when combined with NPK fertilizer it gave better result. As a result of this, *Parkia biglobosa* leaves can be ploughed into the soil and watered for weeks before planting of maize after which NPK fertilizer should be applied to ensure maximum growth and yield of maize crop at lower cost and favourable environmental effects.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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