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Influence of *Gmelina arborea* and *Khaya senegalensis* as Agroforestry Based System on Yield Component of Maize (*Zea mays*) in Borno State, Nigeria

Goni, B.[1], Isah, M.[2], Daya, H.A [3] and Aliyu, A.[1]

[1]Department of Forestry Technology, Mohamet Lawan College of Agriculture, Maiduguri, Borno State, Nigeria.
[2]Department of Farming Systems Research, Lake Chad Research Institute Maiduguri Borno State, Nigeria.
[3]Department of Science Laboratory Technology, College of Agriculture, Science and Technology, Gujba, Yobe State, Nigeria.

Corresponding Author Email: misah3930@gmail.com +2348037928483

Abstract: The study assessed the influence of *Gmelina arborea* and *Khaya senegalensis*, as agroforestry based systems on yield components of maize in Borno State, Nigeria. The experiment was laid out in a Randomized Complete Block Design (RCBD), and data on growth and yield parameters were collected and analyzed using Analysis of Variance (ANOVA), mean separation were compared using Duncan's Multiple Range Test (DMRT). Results indicated that Maize grown under *Gmelina arborea* exhibited higher growth and yield compared to *Khaya senegalensis*. Moreover, increasing manure rates improved plant height, number of leaves, and cob length, while reducing days to maturity, silking, and the anthesis-silking interval. The highest cob yield (2481.8 kg/ha), grain yield (1859.5 kg/ha), and hundred seed weight (169.33 g) were recorded at 60.0 t/ha manure rate, which significantly outperformed the control (0.0 t/ha) with 1036.8 kg/ha, 794.3 kg/ha, and 113.17 g, respectively. *Gmelina arborea* produced higher (2328.4 kg/ha) cob yield, grain yield (1769.4 kg/ha), and hundred seed weight (150.83 g) compared to *Khaya senegalensis* (1391.0 kg/ha, 1104.2 kg/ha, and 138.42 g). The findings concluded that *Gmelina arborea* plantation provides better growing conditions for maize than *Khaya senegalensis* plantation and maize productivity increases with increase in manure rates irrespective of the plantation. The recommended the combination of higher rates of manure and using fast growing species such as *Gmelina arborea* as agroforestry based trees for optimum yield of the component crops.
Keywords: Agroforestry, Environmental sustainability, Manure rates, Plantation, Yield

INTRODUCTION

Agriculture is the backbone of Nigeria's economy, providing livelihoods for over 70% of the population and contributing significantly to the nation's Gross Domestic Product (GDP) (Bello 2020). However, agricultural productivity in semi-arid regions like Borno State is constrained by many factors among which is lack of access to farm lands due to Boko Haram insurgency, poor soil fertility, erratic rainfall, and land degradation among others. Maize (*Zea mays* L.) is a staple crop widely cultivated in Nigeria, serving as a critical source of food and income for smallholder farmers (Chiaka*et al*. 2022). The white maize variety is particularly popular due to its adaptability and high yield potential. However, achieving optimal maize productivity in semi-arid regions requires innovative agricultural practices that enhance soil fertility and mitigate environmental stresses.

Agroforestry, the integration of trees with crops and/or livestock, has emerged as a sustainable land-use system that addresses soil fertility decline, biodiversity loss, and climate change impacts (Kumar *et al*. 2023). Trees such as *Gmelina arborea* and *Khaya senegalensis* are commonly used in agroforestry systems due to their ability to improve soil structure, enhance nutrient cycling, and provide microclimatic benefits (Sileshi *et al*., 2023). These trees can also contribute to carbon sequestration and biodiversity conservation, making them valuable components of

sustainable agricultural systems. Organic manure is an important component of soil fertility management, particularly in resource-constrained farming systems. It improves soil organic matter, enhances water retention, and provides essential nutrients for crop growth (Zingore *et al*., 2021). The application of manure at varying rates can significantly influence crop performance, especially in nutrient-deficient soils. However, the optimal manure application rate for maize production under agroforestry systems in semi-arid regions remains understudied. This study is aim to assess the growth and yield performance of TZEVDT white maize under *G. arborea* and *K. senegalensis* based agroforestry systems, to determine the effect of varying manure application rates (0, 20, 40, and 60 t/ha) on maize productivity, and also to identify the best combination of agroforestry system and manure rate for maximizing maize yield in semi-arid conditions.

MATERIALS AND METHOD

Study Area

The study was carried out in Mohamet Lawan College of Agriculture along Dikwa road in Maiduguri, Borno State, Nigeria. The college is located between latitude 11°86' - 11°91' N, and longitude 13°21' – 13°26' E (Shettima, 2017). The college shares borders with Goni Kachallari, 505 Housing estate, Shokwari to the west and Farm center towards the northeastern part. The area is characterized by two distinct seasons namely; wet and dry seasons. The wet season occurs between July and October with average annual rainfall of 500 – 600mm, August usually been the wettest month, with heavy sporadic rain showers while dry season last from November to June with virtually no rainfall during these months. The temperature is high throughout the year, with average high temperatures range from 30^0C – 40^0C whereas average low temperatures range from 14^0C – 25^0C the area mostly experience March – May as the hottest months exceeding 40^0C, December and January are relatively cooler, with nighttime temperatures occasionally dropping to around 14^0C. The vegetation of the study are is an open savannah, characterized by predominantly fewer and dispersed trees such as *Azadirachta indica*, *Eucalyptus camaldulensis*, and *Acacia seyel*, shrubs (*Calatropis procera etc*) and predominantly covered by grasses such as *Andropogan gayanus*, *Pennisetum purpureum*, *Imperata cylindrica*, and *Cenchrus ciliaris* among others and thus forest formations (Shettima 2017).

Experimental Design

The experiment was carried out in two adjacent plantations at the college academic premises in 2017 cropping season, to find out the suitable agroforestry and best manure (Cow-dung) rate for optimum yield of maize. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three (3) replications. The plot size were 4m x 7m, maintaining 50cm x 75cm intra and inter row spacing with four (4) treatment combinations (0, 20, 40, and 60 t/ha) under each of the two (2) *G. arborea* and *K. senegalensis* plantations. The plots and replications were separated by 0.5 and 1.0 m unplanted boarder respectively. Manual hoe-weeding were done at 3, 6 and 9 weeks after sowing to keep the experimental field weed free. All other agronomic practices (thinning, earthing-up, pest and diseases control) for maize production were kept normal and uniform for all the treatments in both plantations.

Data collection and Analysis

Data on growth (plant height, days to tasselling and days to silking etc) and yield parameters (number of rows per cob, number of grains per cob and hundred grain weight etc) were collected, yield per plot was converted to Kg/ha. All data collected were subjected to analysis of variance (ANOVA) and the differences among the means were separated at 5% level of probability using Duncan's Multiple Range Test (DMRT) with the help of statistical software STATISTIX 8.0. (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Table 1 present the results on growth parameters of maize as affected by manure rates and the agroforestry based system (plantation). The results showed significant ($p<0.05$) difference among manure rates for all the parameters observed and between plantations except the number of leaves. The interactions of manure rate by type of plantation is not significant ($p>0.05$) throughout the parameters observed except for days to silking. The plant height at harvest ranged from 97.43 cm to 136.07, where 60.0 t/ha and 40.0 t/ha had the tallest and statistically similar height of 136.07 and 133.45 cm respectively, whereas 0.0 t /ha had the shortest height of 97.43 cm. Similarly, number of leaves ranged from 12.77 to 15.25, plots with 60.0 t/ha recorded the highest number of leaves and closely followed by 40.0 t/ha with the average values of 15.25 and 14.53 respectively, 0.0 t/ha recorded 12.77 leaves that is not significantly different from 13.27 produced by 20.0 t/ha. This could be attributed to nutrient availability and uptake that enhance photosynthesis as buttressed in the report of Shao *et al*. (2024) which stated that, increase in application rate of cattle manure resulted in the tallest maize plants, that is attributed to improved nutrient availability (N, P, K) and enhanced photosynthesis.

The results also revealed that 0.0 t/ha produced significantly longer day to Tasselling, days to silking and anthesis to silking interval with corresponding 51.33, 59.83 and 8.50 days respectively, followed by 20.0 t/ha with 48.67, 55.00 and 6.33 days respectively. The shorter days to tasselling, days to silking and

anthesis to silking interval is recorded in highest rate of 60.0 t/ha with average days of 47.00, 52.83 and 4.50 respectively. This might be as result of nitrogen level contained in cow-dung as suggested by Hammad *et al*. (2011) who reported that Nitrogen rates significantly influenced days to maturity in maize the relationship was found to be highly correlated.

The result further showed that 60.0 t/ha produced longer cob length of 10.50cm which is not significantly different from those produced on plots with 40.0 t/ha (10.03cm). The shortest cob length (6.73 cm) was recorded in 0.0 t/ha plots. As opined by Toungos (2020) cow dung application significantly increases maize growth parameters such as plant height, leaf area, and number of leaves. Yield components like cob length, 1000 grain weight, and number of kernels per cob are also positively affected. For the effect of agroforestry system based species (plantation) the results revealed that maize grown under *G. arborea* has the taller plant height, higher number of leaves and longer cobs with 124.51 cm, 14.15 and 9.58 cm respectively, in comparison to 111.84 cm, 13.76a and 8.46 cm recorded under *K. senegalensis* plantation. Maize grown under *K. senegalensis* recorded significantly longer days to tasselling, days to silking and anthesis to silking interval of 49.92, 57.75 and 7.33 as against 47.67, 53.00 and 5.17 under *G. arborea* plantation. This is in agreement with the findings of Deb *et al*. (2015) Increase soil organic carbon and nitrogen, which is beneficial for mitigating climate change and improving soil fertility which could influence the wellbeing of growing plants.

The interaction effect of manure rate x plantation on days to silking of maize showed that the earlier days to silking was recorded on 60.0 t/ha rate under *G. arborea* plantation, followed by 40.0 t/ha of the same plantation, days to silking continue to increase with the decrease in the manure rate while generally maize grown under *K. senegalensis* took longer days to silking compared to those grown under *G. arborea* (Table 2).

The yield parameters as influence by manure rate and type of plantation is presented in Table 3. The results showed significant ($p<0.05$) difference among the manure rate and the different plantations across the parameters studied except for the number of row per cob. The interactions of manure rate x plantation is not significant ($p>0.05$) in all the parameters evaluated except for hundred seed weight.

Table 1: Maize Growth Parameters as Influenced by Manure Rate under Different Plantation

Manure rate	Plant height (cm)	Number of leaves	Days to Tasselling	Days to Silking	Anthesis to Silking Interval	Cob Length (cm)
0.0 t/ha	97.43b	12.77c	51.33a	59.83a	8.50a	6.73c
20.0 t/ha	105.75b	13.27bc	48.67b	55.00b	6.33b	8.80b
40.0 t/ha	133.45a	14.53ab	48.17b	53.83bc	5.67b	10.03ab
60.0 t/ha	136.07a	15.25a	47.00b	52.83c	4.50c	10.50a
SE±	5.349	0.563	0.579	0.607	0.317	0.451
Plantation						
G. arborea	124.51a	14.15a	47.67b	53.00b	5.17b	9.58a
K. senegalensis	111.84b	13.76a	49.92a	57.75a	7.33a	8.46b
SE±	3.782	0.398	0.410	0.429	0.224	0.319
Interaction	Ns	Ns	Ns	*	Ns	Ns

Means followed by same letter(s) in the same column are statistically similar using Duncan's Multiple Range Test (DMRT) * = Significant at 5% probability level, Ns= Not significant at 5% probability of F-test

Table 2. Interaction Effect of Manure Rate x Plantation on Days to Silking of Maize

	0.0 t/ha	20.0 t/ha	40.0 t/ha	60.0 t/ha
G. arborea	59.33^{ab}	52.33^{d}	50.33^{d}	50.00^{d}
K. senegalensis	60.33^{a}	57.67^{bc}	57.33^{bc}	55.67^{c}
SE±	0.8580			

Although the number of row per cob is statistically similar ($p>0.05$) among the treatments, the highest number of raw was recorded in 20.0 t/ha (13.93) and 0.0 t/ha had the least of 13.00 rows. The result also shows that, number of grains per cob ranged from 19.49 to 30.42 with 60.0 t/ha having the highest number of grain and closely followed by 40.0 t/ha with corresponding 30.42 and 28.17 respectively. The least number of grains per cob was recorded in 0.0 t/ha with the average of 19.47 grains. The cob yield, grain yield and hundred seed weight ranged from 1036.8 to 5481.8 kg/ha, 794.3 to 1859.5kg/ha, and 113.17 to 169.33g respectively. The highest cob yield, grain yield kg/ha and hundred seed weight were recorded under manure treatment of 60.0 t/ha with the average values of 2481.8 kg/ha, 1859.5kg/ha and 169.33g respectively, followed by 40.0 t/ha with 2145.4kg/ha, 1693.4kg/ha and 157.00g. The least in term of cob yield, grain yield and hundred seed weight is recorded under 0.0 t/ha treatment with corresponding values of

1039.8kg/ha, 794.3kg/ha and 113.17g respectively. As encapsulated in report of Naveed *et al*. (2023), the application of cow dung enhances nutrient availability, leading to improved growth and yield parameters of maize. Similarly, Ezenne *et al*. (2019) stated that cow dung improves soil physical properties by increasing porosity, moisture content, and infiltration rate while reducing bulk density and soil temperature. These changes create a more favorable environment for maize growth. Conversely, Loncaric *et al*. (2020) has reported that 10 t/ha cow manure achieved yields comparable to 20 t/ha, making it more cost-effective.

The effect of agro-forestry based plantation on maize yield parameters indicated that *G. arborea* had the highest number of row per cob, grains per cob, cob yield in kg/ha, grain yield kg/ha and hundred seed weight with the average values of 13.75, 27.68, 2328.4, 1769.4 and 150.83 respectively, which is in contrast to 13.18, 23.53, 1391.0, 1104.2 and 138.42 produced under K. senegalensis. This is in line with the report of Ignace *et al*. (2018), who states that different tree species can influence soil organic carbon levels. In a similar view by Zarafshar*et al*. (2020) type of plantations can stimulate soil biological activities and enzyme production, which is crucial for nutrient cycling and soil fertility. However, the impact may vary depending on the tree species.

The interaction effect of manure rate x plantation on hundred seed weight of maize showed that the highest weight of 175.33g was recorded on 60.0 t/ha under *K. senegalensis* plantation, followed by 40.0 t/ha under *G. arborea* with 167.67g. Generally, hundred seed weight is higher under *G. arborea* in all the manure rates except 60.0t/ha, the least weight of hundred seeds is produced by 0.0t/ha under *K. senegalensis* with 111.33g (Table 4).

Table 3. Maize Yield Parameters as Influence by Manure Rate under Different Plantation

Manure rate	Number of Rows /Cob	Grain/Cob	Cob Yield (kg/ha)	Grain yield (kg/ha)	Hundred seed weight (g)
0.0 t/ha	13.00b	19.47c	1036.8b	794.3b	113.17c
20.0 t/ha	13.93a	24.37b	1774.9ab	1400.0ab	139.00b
40.0 t/ha	13.43ab	28.17a	2145.4a	1693.4a	157.00a
60.0 t/ha	13.50ab	30.42a	2481.8a	1859.5a	169.33a
SE±	0.243	0.977	256.50	208.01	4.684
Plantation					
G. arborea	13.75a	27.68a	2328.4a	1769.4a	150.83a
K. senegalensis	13.18b	23.53b	1391.0b	1104.2b	138.42b
SE±	0.17	0.69	181.38	147.08	3.312
Interaction	Ns	Ns	Ns	Ns	*

Means followed by same letter(s) in the same column are statistically similar using Duncan's Multiple Range Test (DMRT) * = Significant at 5% probability level, Ns= Not significant at 5% probability of F-test

Table 4. Interaction Effect of Manure Rate x Plantation on Hundred Seed Height of Maize

	0.0 t/ha	20.0 t/ha	40.0 t/ha	60.0 t/ha
G. arborea	115.00c	157.33ab	167.67a	163.33ab
K. senegalensis	111.33c	120.67c	146.33b	175.33a
SE±	6.624			

CONCLUSION AND RECOMMENDATION

It was evident from the study that increasing manure rates significantly improve maize growth and yield especially under fast growing and high defoliating species like *Gmelina arborea* that gives a more favorable environment for maize cultivation, and recommend the combination of higher rates of manure in *Gmelina arborea* plantation to optimize maize productivity compared to *Khaya senegalensis*. Further research should explore long-term effects of these practices on soil health and performance of maize or other component crops.

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