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INFLUENCE OF LEAFY BIOMASS TRANSFER OF AGROFORESTRY TREES WITH NITROGEN FERTILIZER ON MAIZE STOVER YIELD IN MAKERA, NIGERIA

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ABSTRACT

Cultivation of leguminous tree crops and biomass transfer is the main possibility for soil enrichment with nutrients, especially with nitrogen and play alternative role as source of organic fertilizer. This study investigated the influence of leafy biomass transfer of Albizia lebbeck and Parkia biglobosa leguminous agroforestry trees with urea on maize stover yield. A 3 x 4 x 2 factorial design in a split-split plot design was used for this experiment in three replicates for two years. The considered factors were; biomass species (Albizia lebbeck and Parkia biglobosa, and control) as main plots, four rates of nitrogen (0, 40, 80, 120 kg N ha^{-1}) as sub-plots, and two maize varieties (DMR-ESR-7 and 2009 EVAT) as sub-sub plots. Data were statistically analysed using (ANOVA) at p =.05. Albizia lebbeck decomposed (38.2 g) faster than Parkia biglobosa (28.16 g). Decomposition rate constant (KD) and nitrogen release rate constant (KN) was higher in Albizia with the mean values of 15.04 week^{-1} and 10.74 week^{-1} than in Parkia (9.94 week^{-1}, 7.89 week^{-1}) in both seasons respectively; and this enhanced maize crop to promptly utilise the nutrient release in Albizia lebbeck. The result revealed that Albizia lebbeck leafy biomass alone brought about increase in stover yield. Nevertheless, addition of 120 kg N ha^{-1} urea produced higher stover yield in 2009 EVAT. Therefore, amendment of soil with Albizia lebbeck biomass and up to 40 kg N ha^{-1} urea improved soil quality and enhanced better stover yield production.

Keywords: leafy biomass, transfer, agroforestry trees, urea, nutrient release, maize stover yield.

INTRODUCTION

The increase in population of developing countries has influenced the production, supply and demand for goods and services, especially in urban areas. Shortage of food in most of these countries is a function of population explosion and rural urban migration, environmental hazards (drought, flood etc), low level of technology, attitude of people towards farming (some people believed that farming is meant for poor people), land hunger and widespread soil infertility (Olujobi and Oke, 2005).

The use of inorganic fertilizers can improve crop yields and soil pH, total nutrient content, and nutrient availability, but its use is limited due to scarcity, high cost, nutrient imbalance and soil acidity. The use of organic manure as a means of maintaining and increasing soil fertility has been advocated (Smil, 2000). Nutrients contained in manures are released more slowly and are stored for a longer time in the soil, ensuring longer residual effects, improved root development and higher crop yields (Abou El Magd *et.al.*, 2005).

Leguminous trees that are nitrogen fixing trees are known to play a complementary or alternative role as source of organic fertilizer and have the potential to sustain soil fertility (Giller, 2001; Snapp *et al.*, 2003; Adjei-Nsiah *et al.*, 2004). Biomass transfer is essentially moving green leaves and twigs of fertiliser trees or shrubs from one location to another, usually in the wetlands to be used as green manure. Recent studies (Kuntashula *et al.*, 2004) have shown that biomass transfer using fertiliser tree species is a more sustainable means for maintaining nutrient balances in maize-based production systems. The advantage is that synchrony between nutrient release and crop uptake can be achieved with well-timed biomass transfer. The management factors that can be manipulated to achieve this are litter quality, rate of litter application, and method and time of litter application (Mafongoya *et al.*,1998).

Although it has been argued that biomass transfer technologies require a lot of labour for managing and incorporating biomass, economic analyses have concluded that it is unprofitable to invest in biomass transfer when labour is scarce and its cost is thus high (Kuntashula *et al.*,2004, 2006). In addition to increasing yields of crops, biomass transfer has shown potential to increase yields of high-value crops like maize (Kuntashula *et al.,* 2004, 2006).
Low soil fertility is widely recognized as a major obstacle to improving agricultural productivity in sub-Saharan Africa (Sanchez, 2002). In most regions of Africa, soil fertility degradation is caused by three interlinked factors: (i) the breakdown of the traditional fallow system as a result of an increase in human population and decreasing per-capita land availability, which forced farmers to crop continuously and encroach on marginal lands in search of more fertile lands; (ii) inadequate adoption of soil management investments such as conservation or crop residue incorporation; and (iii) sub-optimal use of fertilizers by a majority of smallholder farmers due to high cost and constraints to access them.

Improved fallows, or the rotation of deliberately planted fast-growing nitrogen-fixing legumes with cereals, have been considered recently as convenient entry points to address the soil fertility problem in Africa (Kwesiga *et al.,* 1999; Mafongoya and Dzowela, 1999). Researchers, therefore, continue to explore ways of incorporating nitrogen-fixing herbaceous and tree legumes into production systems to increase availability of N to maize (Sanchez, 2002), reducing pest damage and weed competition (Sileshi and Mafongoya, 2003; Sileshi *et al.,* 2005).

MATERIALS AND METHODS

Study Area

Makera is the study area, a village in Dutsinma Local Government Area of Katsina State (Figure 1), having an area of 527 km², altitude of 605 m and a population of 169, 671 (Tukur *et al.,* 2013).

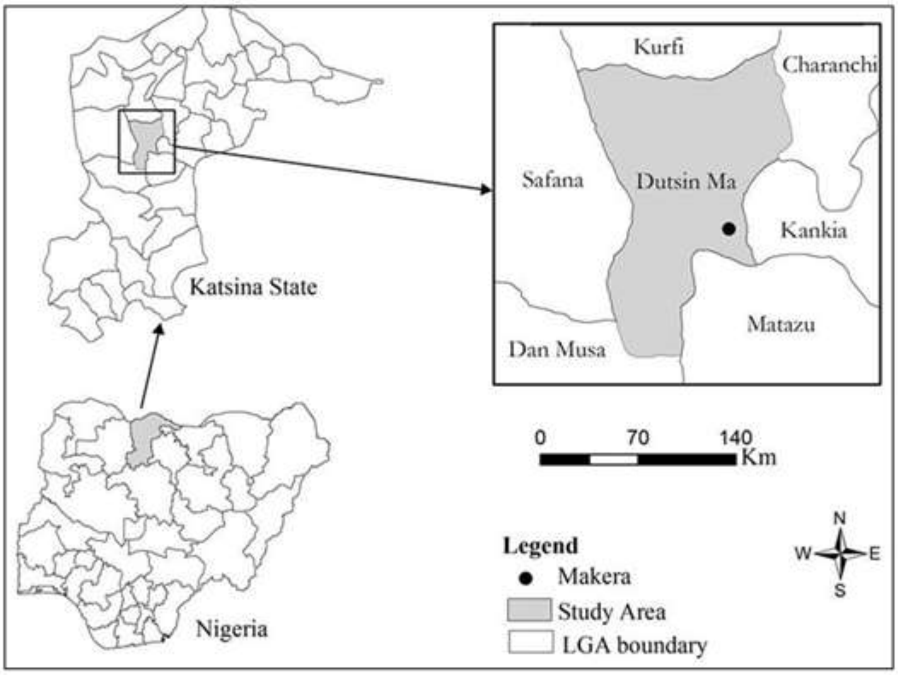

Figure 1: Map of Dutsinma Showing Makera (the Study Site)

Experimental Design

The experiments were laid out in a split-split plot design using a 3 x 4 x 2 factorial design with three replicates. The plot dimensions were 4 m x 3 m. Leafy biomass of *Albizia lebbeck* and *Parkia biglobosa* were pruned and incorporated fresh into the soil at the rate of 6 kg for each (5000 kg ha^{-1}) of the *Albizia* and *Parkia* biomass plots (B_1 and B_2) respectively and plots without incorporation of leafy biomass (B_0). The leafy biomass was incorporated into the soil for two cropping season in 2014 and 2015. Four levels of N fertilizers were split applied as: $N_{0,}$ 0 kg N ha^{-1} (control); N_1, 40 kg N ha^{-1}; N_2, 80 kg N ha^{-1}; N_3, 120 kg N ha^{-1} and half were applied at 2 weeks after planting (WAP). The remaining amount was applied 5 WAP. The two varieties of maize used were (DMR- ESR- 7 (Yellow Maize) and 2009 EVAT (White Maize) which were obtained from Katsina State Agricultural and Rural Development Authority (KTARDA). The two maize varieties were planted (two maize seeds were planted per hole, at equal depth and this later thinned to one seed per hole after germination) using the conventional spacing of 75 cm x 25 cm two weeks after incorporation of leafy biomass of *Albizia* and *Parkia* into the soil. Thinning was also done 2 WAP making the total plant population of 64 stands per plot.

Plant Tissue Analysis of Agroforestry Tree Species

Samples of harvested leaves were air dried at room temperature and ground and analysed for initial contents of N, C, lignin and polyphenols. Total N was analysed by Macro-Kjeldahl digestion, followed by distillation and titration (Anderson and Ingram, 1993; Brandstreet, 1965). Lignin were determined by the Acid Detergent Fibre (ADF) Method (Anderson and Ingram, 1993). The polyphenol was extracted in hot (80^0 C) 50 % aqueous methanol and determined calorimetrically with tannic acid as a standard measurement (Anderson and Ingram, 1993; Hagerman, 1988).

Data Collection

Five maize plants were randomly selected within each of the net plots4 m x 1.5 m (6 m^2) with a tag for periodic observations at 4, 6, 8 and 10 WAP during the crop growth cycle for pre- harvest data collection. At harvest, these same five tagged plants were still used to obtain yield.

Statistical Data

Collected data were subjected to Analysis of Variance using Statistical Analysis System (SAS, 2003) computer package at 5 % level of significance to determine differences in the treatment effect. The Duncan's Multiple Range Test (Duncan, 1955) was used to separate means of differences among the treatments.

RESULTS

Selected Soil Physical and Chemical Properties before Planting

Soil physical and chemical properties before the experiment started appear in Table 1. The soil was low in total nitrogen and organic carbon (0.04 % and 0.53 % respectively). The soil distribution of exchangeable basic cations followed this order: Ca>Mg>Na>K. Nitrate-nitrogen was higher than ammonia-nitrogen in the soil. The pH of the soil was acidic. The soil belongs to the textural class sandy loam.

Table 1:Soil physical and chemical properties of site soil before establishment of the experiment

Soil properties	Value
Particle size (gkg^{-1})	
Sand	88.60
Silt	4.00
Clay	7.40
Textural class	Sandy loam
Chemical properties	
pH	4.10 (acidic)
Organic carbon (%)	0.53
Total nitrogen (%)	0.04
NH_4^+N ($mgkg^{-1}$)	23.99
NO_3^-N($mgkg^{-1}$)	26.38
Available phosphorus (mg kg^{-1})	7.94
Exchangeable bases (C mol kg^{-1})	
Ca	6.25
Mg	1.01
K	0.20
Na	0.35
Exchangeable acidity (C mol kg^{-1})	
Al^+	0.15
CEC	7.96
Micro nutrients (mg kg^{-1})	
Mn	30.10
Fe	11.00
Cu	1.45
Zn	6.50

Decomposition Patterns of Plant Residues

50 g fresh weight of biomass was put inside litter bags for their decomposition. There was a general rapid loss of mass from the litter bags during the first two weeks after planting (2 WAP) for the two species (Figure 2) in this order *Albizia lebbeck* (38.2g) < *Parkia biglobosa* (28.16 g) compared to initial weight of 50 g. At the end of four weeks after planting (4 WAP), *Albizia lebbeck* had lost 42.19 g of its initial weight while 30.04 g of *Parkia biglobosa* had been decomposed. At 6 WAP, the rate of mass loss due to decomposition declined in both species. Even then, *Albizia lebbeck* continued to decompose faster compared with *Parkia biglobosa*. Moreover, decomposition continued as the experiment progressed

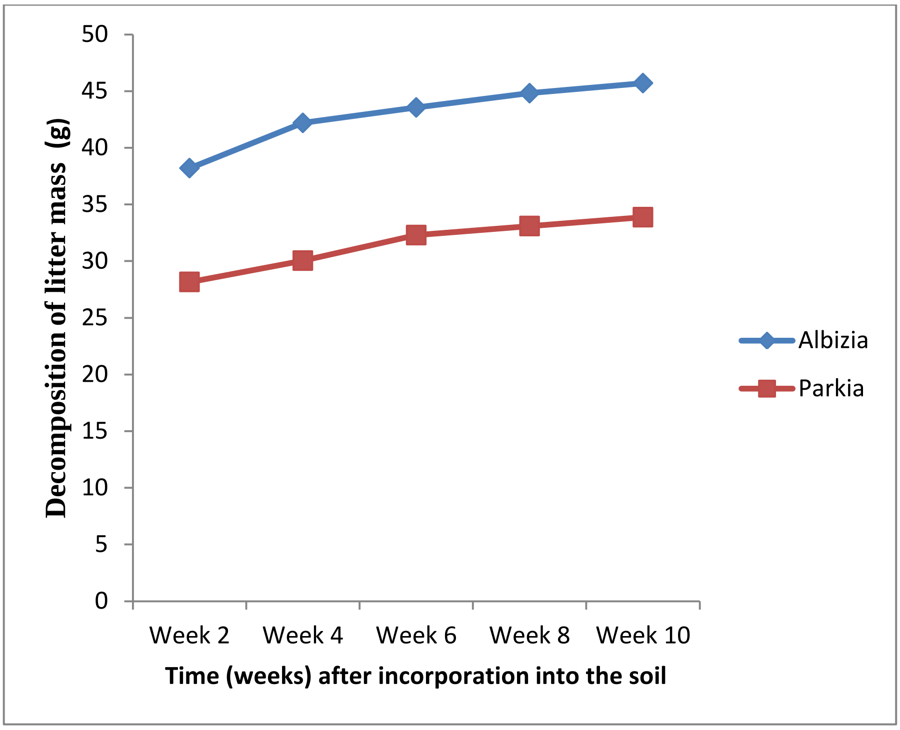

Figure. 2: Loss weight of *Albizia lebbeck* and *Parkia biglobosa* leafy biomass over a period of 10 weeks

Chemical Composition of *Albizia lebbeck* and *Parkia biglobosa* Leafy Biomass

The plant materials showed variations in their chemical compositions during 2014 and 2015 cropping seasons (Table 2). The leaves of *Albizia* c ontained higher N (leading to lower C: N ratio) than *Parkia*. *Albizia* had higher concentration of lignin with mean value of 11.06, while *Parkia* had higher C: N ratios with mean value of 6.30. Table 2 revealed that, *Parkia biglobosa* had lower N and C contents.

Table 2: Initial chemical composition of the biomass of *Albizia lebbeck and Parkia biglobosa* plant species before decomposition commenced

Component	N %	C %	Lignin %	Polyphenol %	C: N
Albizia lebbeck					
2014	3.32a	18.62a	11.37a	0.65b	5.60b
2015	3.16a	18.65a	10.74a	0.48b	5.90b
Means	3.24a	18.64a	11.06a	0.57b	5.75b
Parkia biglobosa					
2014	2.85b	17.81b	8.35b	0.87a	6.20a
2015	2.44b	15.52b	8.13b	0.63a	6.40a
Means	2.65b	16.67b	8.24b	0.75a	6.30a

N= Nitrogen; C= Carbon; C:N= Carbon/N ratio

Means followed by the same letter(s) within the same column and treatment are not significantly different ($p > 0.05$)

Decomposition Rates and N Release Patterns of Plant Residues

The decomposition rate (*KD*) and N release rate (*N*) constants among *Albizia* and *Parkia* leafy biomass were significantly different ($p < 0.05$) from each other during the two seasons (Table 3). *Albizia* biomass had higher *KD* and *KN* rate constants, meaning that, it had more rapid decomposition and N release rates than *Parkia biglobosa.*

Table 3: Decomposition rate and N release constants and their coefficient of determination values for *Albizia lebbeck and Parkia biglobosa* residues in the semi-arid of Nigeria

Season	**Plant residue**	**kD**	**R^2**	**kN**	**R^2**
2014	*Albizia*	15.07a	0.98	10.81a	0.99
	Parkia	9.18b	0.98	7.92b	0.99
2015	*Albizia*	15.00a	0.93	10.67a	0.98
	Parkia	10.69b	0.93	7.85b	0.98

KD = decomposition rate values are *k*/week, *KN* = N release values are *k*/week, R^2 =coefficient of determination.
Means followed by the same letter within a column in a particular farming season are not significantly ($p < 0.05$) different at 5 % level of probability

Maize Stover Yield (kg N ha^{-1})
In 2014 and 2015 as well as their combined means, there was no significant difference in all the treatments on maize stover yield. In 2014, 2015 and combined means, the control treatments produced significantly lower values (2435 kg ha^{-1}, 2694.4 kg ha^{-1}, 2564.8 kg ha^{-1}) of stover yield than in plots supplied with other N rates. In 2014, 2015 and their combined means 2009 EVAT produced significantly higher values (6319.4 kg ha^{-1}, 4611.1 kg ha^{-1}, 5465.3 kg ha^{-1}) on stover yield than DMR-ESR-7 (Table 4).

Table 4: Influence of biomass and nitrogen rate on stover yield (kg ha^{-1}) of two maize varieties in 2014 and 2015

	Stover yield (kg ha^{-1})		
Treatment	2014	2015	Combined
Biomass (B)			
Control	4652.8a	3708.3a	4180.6a
Albizia	5840.3a	3777.8a	4809.0a
Parkia	5180.6a	3013.9a	4097.2a
SE±	749.81	395.83	443.12
Nitrogen (N) Kg ha-^{1}			
0	2435.0b	2694.4b	2564.8b
40	5426.0a	3611.1ab	4518.5a
80	5861.0a	3648.1ab	4754.6a
120	7176.0a	4046.3a	5611.1a
SE±	722.27	446.11	452.44
Variety (V)			
DMR-ESR-7	4129.7b	2388.9b	3259.3b
2009 EVAT	6319.4a	4611.1a	5465.3a
SE±	573.29	256.65	330.29
Interaction			
B x N	S*	NS	S*
B x V	NS	S*	S*
V x N	S*	S*	S*

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5 % level of probability using DMRT. S* Significant at 5 % level of probability. NS: Not significant.

Biomass and Nitrogen Interaction

Albizia lebbeck amended plots had higher yield value (6194.5 kg ha^{-1}) of stover yield at 120 kg N ha^{-1} than all other N rates application (Table 5). Note that you planted two varieties of maize.

Table 5: Interaction between biomass and nitrogen rate on maize stover yield (kg ha^{-1}) in combined analysis

	Nitrogen (Kg ha^{-1})			
Treatment	0	40	80	120
Biomass (B)				
Control	2208.3c	4722.2abc	4930.6abc	4861.1abc
Albizia	3250.0bc	5055.6ab	4736.1abc	6194.5a
Parkia	2236.1c	3777.8abc	4597.2abc	5777.8ab
SE±		777.95		

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT.

Biomass and Variety Interaction

Comparable values were obtained among biomass treatments regardless of the variety, where *Albizia lebbeck* and 2009 EVAT had significantly higher yield value (6007 kg ha^{-1}) of maize stover yield than *Parkia biglobosa* and control and with DMR-ESR-7 (Table 6).

Table 6: Interaction between biomass and variety on maize stover yield (kg ha^{-1}) in combined analysis

	Variety	
Treatment	DMR- ESR-7	2009 EVAT
Biomass (B)		
Control	3312.5cd	5048.6abc
Albizia	3611.1bcd	6007.0a
Parkia	2854.2d	5340.3ab
SE±	573.47	

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5 % level of probability using DMRT.

Variety and Nitrogen Rate Interaction

2009 EVAT produced significant higher value (7787 kg ha^{-1}) of stover yield at 120 kg N ha^{-1} than DMR-ESR-7 at all N rates (Table 7).

Table 7: Interaction between variety and nitrogen rate on stover yield (kg ha^{-1}) in combined analysis

	Nitrogen (Kg ha-^{1})			
Treatment	0	40	80	120
Variety (V)				
DMR- ESR- 7	2046.3d	3509.cd	4046.3bc	3435.2cd
2009 EVAT	3083.3cd	5527.8b	5463.0b	7787.0a
SE±		572.02		

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5 % level of probability using DMRT.

DISCUSSION

The soil was initially low in total nitrogen and organic carbon, while the pH of the soil was acidic. The soil distribution of exchangeable basic cations fallowed this order: Ca>Mg>Na>K. The soil textural class was sandy loam. *Parkia biglobosa* had low N and C contents which had means of 2.65 % N and 16.67 % C respectively, with high C: N ratio which had a mean value of 6.30. It was observed that good performance in plots amended with *Albizia lebbeck* was due to the high quality of the plant nutrient materials resident in it (Oyebamiji *et al.*, 2017). N released from the two leguminous plants partly followed the same pattern as decomposition rate for the first two weeks. Over 56 % of N from the two biomass species in the litter bags were released during the first two weeks of incubation. So, the N content in the remaining undecomposed litter generally increased with time. Torreta and Takeda (1999) and De Costa and Atapattu (2001) reported that weight loss of biomass has generally taken place in the first 2-4 weeks, since the physical and biological process occurred faster at this level and most of the weights are lost. Observations from *Albizia lebbeck* leafy biomass revealed high decomposition and N release rate constants over *Parkia biglobosa* biomass. Biomass decomposition will basically cause changes in condition in the soil due to the influence of biological and abiotic factors. The decomposition of legominous biomass is an important aspect in nutrient cycle due to its determination on the level of the cycled nutrients becomes available to plants (Matheus *et al.*, 2013). Weight loss of biomass during decomposition period is an indicator to estimate the rate of decomposition (Matheus *et al.*, 2013).

High lignin and polyphenol content in organic materials prevent rapid mineralization process due to their ability to bind proteins, and hence, they determine the quality of organic materials to be decomposed by soil microbes (Handayanto *et al.*, 1997). Therefore, it is important to note that decomposition and nutrient release are governed by the chemical composition of the plant materials.

Since, *Albizia lebbeck* biomass decomposed and mineralized faster, nutrient uptake was easy to aid yield production. The higher yield of maize stover was directly related to the greater availability of soil N possibly resulting from the decomposition of the incorporated *A. lebbeck* biomass. Organic matter content from the decomposing leaf biomass could have improved the chemical properties of the soil important for good plant growth. Decomposition of *A. lebbeck* had higher significant effect on stover yield and this confirms the report of Agyeman *et al*. (2012) who stated that increase in stover yield is experienced when leafy biomass was applied to maize. In comparison, there were no significant differences among the two species of biomass in all the cropping seasons and in their combined means. Even though, *Albizia lebbeck* biomass produced significantly higher yield value on maize stover yield than *Parkia biglobosa*. The significant interactions between biomass and nitrogen rate on stover yield showed that the combination of any of the biomass and N rates especially *Albizia*; apart from the control was the best combination for increased maize stover yield due to increased mineralized nutrients and N fertilizer readily available for the maize crops.

But, in terms of increase in maize stover yield rate, application of N from 40 kg N ha^{-1} to 120 kg N ha^{-1} had an increasing effect on stover yield. So, urea at 120 kg N ha^{-1} with 2009 EVAT produced increased stover yield, and this agreed with El-Gizawy (2009) who reported that increased N application increased maize yield components. Buah *et al.* (2009) also reported that application of N at 120 kg N ha^{-1} currently produced the highest stover yield of maize in the Semi-Arid, Nigeria.

CONCLUSION

Chemical composition of the *Albizia lebbeck* and *Parkia biglobosa* or residues determined quickness or slowness of decomposition and nutrient release of the plant residues. Leafy biomass of *Albizia lebbeck* gave increased maize stover yield. All the same, incorporation of *Albizia lebbeck* with urea (120 kg N ha^{-1}) produced higher stover yield in 2009 EVAT. Hence, incorporation of *Albizia lebbeck* up to 40 kg N ha^{-1} improved soil quality and enhanced maize stover yield production.

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We acknowledge the support of entire Makera community and herdsmen for creating an enabling environment for me to carry out my research in their area.

Recommendation

1. The incorporation of *Albizia lebbeck* leaves enhanced the growth and yield of maize stover than *Parkia biglobosa* leaves.
2. Farmers are encouraged to use *Albizia lebbeck* leaves as mulch to enrich their soil for better

production of maize in case of unavailability of inorganic fertilizers.

3. Fresh leafy biomass of *Albizia lebbeck* at the rate of 5000 kg ha^{-1} at least could be pruned and incorporated into the soil to retain its fertility.

4. To achieve increased and maximum maize production in Sudan savanna and semi-arid zones of Nigeria with reduced use in inorganic or chemical fertilizers there is a need to consciously adopt the technology of biomass transfer from leguminous trees which can be returned into the soil could be used to argument indigenous cropping system in order to improved soil fertility in a friendly manner.

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