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Fertilization of Maize and Its Impact on Yield Component of Harvest Index

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Abstract
Application of organic and inorganic fertilizers to ameliorate low soil fertility is a common practice. The experiments were laid out as 3x4x2 factorial in a split-split plot design with three replicates for two years. These 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 =0.05. This study assessed fertilization of maize and its impact on yield component of harvest index. A. lebbeck biomass had significant higher influence on harvest index (23.4 kg ha^{-1}) compared to P. biglobosa. Addition of urea fertilizer increased production of maize varieties compared to control. Biomass incorporation and urea application on maize performance established A. lebbeck with 40 kg N ha^{-1} and above rate of urea fertilizer to produce higher maize harvest index. Incorporation of A. lebbeck with reduced rate of 40 kg N ha^{-1} fertilizer improved the yield of 2009 EVAT and DMR-ESR-7 maize varieties. It is therefore recommended as a model to farmers to improve the production of their maize crop yield components.
Keywords: *Leafy biomass, urea fertilizer, maize, yield component, harvest index, farmers*

Introduction

It is of note to know that 'Agroforestry' has a very important role to play in increasing food security and hence improving nutrition and alleviating poverty (Mbwambo *et al.,* 2006). This is due to the fact that agroforestry is a dynamic, ecologically based natural resource management system that, through the integration of trees on farmlands and rangelands, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (Leakey, 1996). However, success of any agroforestry system relies heavily on the choice of suitable tree species that should offer diversity of benefits and show compatibility with food crops (Edward *et al.,* 2006).

Farmers in many occasions cultivate crops, mostly maize every year without addressing soil fertility problem (Ajayi *et al*., 2007; Oyebamiji *et al*., 2016) however they have to because this is their only means of sustaining their livelihoods. Soil fertility remains one of the primary constraints to productive agriculture in arid and semi-arid Africa (Gruhn *et al*., 2000). Nevertheless, the major problem facing cropping systems in the tropics is the reduction in soil productivity that accompanies most systems of continuous cultivation.

Moreover, that is why, addition of plant residue has become a pivotal strategy for soil fertility improvement and sustainable land use (FAO, 2002). Plant residue in any agricultural system is an important source of carbon and nutrient for the growth of crops. Organic resources play an essential role in soil fertility management in the tropics by their short-term effects on nutrient supply and longer-term contribution to soil organic matter formation (Palm *et al*., 2001). The decomposition rate and the amount of nutrient release from organic matter, particularly from leguminous trees, determine the short-term benefits of tree residues for crop nutrition (Handayanto *et al*., 1997).

Total dependence on inorganic fertilizers, pesticides, herbicides and growth regulators has gradually prompted researchers for the need to reconsider an alternative to chemical agriculture in the western world. Organic farming has assumed importance as a clear cut alternative because of the increasing cost of chemical inputs and its undesirable impacts on environment. The nutrient content of organic fertilizers vary widely depending on the source and moisture content and there is also the problem of slow and variable release rates of nutrients during decomposition of organic materials (Hseih and Hseih, 1990). Though organic fertilizers supply large quantities of nitrogen required by crops to obtain maximum yield but for a more sustainable productive system, there is the need to supplement organic fertilizers with inorganic fertilizers (Jama *et al.*, 2000; Vanlauwe *et al.*, 2001).

Materials and Methods

Study Area

The study area was Makera, a village in Dutsin-ma Local Government Area of Katsina State. Dutsin-ma has an area of 527 km², it is found within Latitude 12^{0}27'18" N and Longitude 07^{0}29'29"E and it has altitude of 605 m and a population of 169, 829 as at 2006 national census (Federal Republic of Nigeria, 2012). The area receive an annual rainfall of 700 mm, which is spread from May to September. The mean annual temperatures range from 29-31^o C. the high temperature normally occurs in April/May and the lowest in December through February (Abaje, 2007; Tukur *et al.*, 2013).

Experimental Design

The experimental design were 3 x 4 x 2 factorials with three replicates laid in split-split plot design arrangement. The plot contained 4 m x 3 m dimensions. Leafy biomass of *Albizia lebbeck* and *Parkia biglobosa* were pruned and incorporated fresh into the soil at the rate of 5000 kg ha^{-1} of the *Albizia* ($B_{1)}$ and *Parkia* (B_2) biomass plots, and plots without incorporation of any biomass (B_0). The leafy biomass was incorporated into the soil in 2014 and 2015, that is, two cropping seasons. 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). Two maize varieties were planted; two seeds per hole, at equal depth and it was later thinned to one, two weeks after incorporation of leafy biomass of *Albizia* and *Parkia* into the soil. The conventional spacing of 75 cm x 25 cm was used to make the gross plant population of 64 stands and net plot of 32 stands per plot.

Plant Tissue Analysis of Agroforestry Tree Species

Samples of pruned leaves were air dried at room temperature and ground to be analysed for initial contents of N, C, lignin and polyphenols. Total N was analysed by Macro-Kjeldahl digestion, followed by distillation and titration (Brandstreet, 1965; Anderson and Ingram, 1993). Lignin were determined by the Acid Detergent Fibre (ADF) method as outlined in (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 (Hagerman, 1988; Anderson and Ingram, 1993).

Data Collection

Grain yield (kg ha^{-1}): The grain yield was determined at harvest. The harvested cobs from the net plots were sun-dried, shelled, winnowed and the clean grains weighed. Grain yield per hectare was recorded and expressed in kilogram using the formula:

Grain yield in (kg) x 10,000 m^2 / net plot size in (m^2)

Total dry matter (kg ha^{-1}): Total dry matter (kg ha^{-1}) was determined at harvest by cutting the entire plants in each net plot from ground level after they had been properly sun-dried and weighed using Salter scale model 250. The weights per plot were recorded. Total dry matter per hectare was recorded and expressed in kilogram using the formula:

Total dry matter in (kg) x 10,000 m^2 / net plot size in (m^2)
Therefore, harvest index was determined and calculated using the formula:

$$\text{Harvest index (HI)} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Total dry matter (kg ha}^{-1})} \times \frac{100}{1}$$

Data Analysis
Data were analysed using ANOVA by 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 commencement of the experiment is presented in Table 1. The soil is low in total nitrogen and organic carbon with 0.04 % and 0.53 % respectively. The soil exchangeable basic cations follows this order: Ca>Mg>Na>K. Nitrate-nitrogen was higher than ammonia-nitrogen in the soil. The pH of the soil is acidic. The soil belongs to the textural class sandy loam.

Table 1: Soil physical and chemical properties before establishment of the experiment at Makera in 2014.

Soil properties	Value
Particle size (g/kg)	
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

Chemical Composition of *Albizia lebbeck* and *Parkia biglobosa* Leafy Biomass
There was slight difference in plant materials in comparison between *Albizia lebbeck* and *Parkia biglobosa* during 2014 and 2015 cropping seasons. The leaves of *Albizia lebbeck* showed higher N (leading to lower C: N ratio) than *Parkia biglobosa. Albizia lebbeck* had the highest concentration of lignin with mean value of 11.06, while *Parkia biglobosa* had highest C: N ratios with mean value of 6.30. This showed that, *Parkia biglobosa* had lower N and C contents compared with *Albizia lebbeck* (Table 2).

Table 2: Initial chemical composition of the biomass of *Albizia* and *Parkia* plant species

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

Means followed by the same letter(s) within the same column and treatment are not significantly different (P>0.05). N= Nitrogen; C= Carbon; C:N= Carbon/N ratio

Meteorological Data of Air Temperature and Total Rainfall at Makera

2014 cropping season experienced even distribution of rainfall and this resulted in decomposition of the leafy biomass to release nutrients into the soil, and with which maize crop utilized for its production than in 2015 cropping season that rainfall distribution was poorly and unevenly distributed; and maximum temperature was a little higher than that of 2014 which adversely affected the crop performances (Table 3).

Harvest Index

Plots amended with *Albizia lebbeck* had significantly higher values (25.9 kg ha^{-1}, 23.4 kg ha^{-1}) of harvest index than other treatments in 2015 and the combined means. No significant effect of biomass incorporation was observed on harvest index in 2014. In 2014, plots supplied with 40 kg N ha^{-1} had significantly higher value (23.4 kg ha^{-1}) of harvest index than other N rates. No significant response to N rates was observed in 2015 and combined means. In 2015 and combined means, DMR-ESR-7 produced significantly higher value (25.3 kg ha^{-1}) of harvest index than 2009 EVAT. No significant difference among varieties was observed on harvest index in 2014 (Table 4).

Biomass and variety interaction

In combined analysis, *Albizia lebbeck* amended plots sown to 2009 EVAT had significantly higher value (22 kg ha^{-1}) of harvest index than other treatments. Meanwhile, there was no significant difference among biomass treatments in DMR-ESR-7 on harvest index (Table 5).

Variety and nitrogen rate interaction

DMR-ESR-7 produced significantly higher value (25.1 kg ha^{-1}) of harvest index at 40 kg N ha^{-1} than 2009 EVAT at all N rates in combined analysis (Table 6).

Table 3: Meteorological data showing monthly air temperature and total rainfall distribution at 10 days interval during 2014 and 2015 wet seasons at Makera (Katsina State)

	2014			2015		
Month	**Temperature (^{0} C)**		**Rainfall**	**Temperature (^{0} C)**		**Rainfall**
	Max	Min	(mm)	Max	Min	(mm)
May						
1-10	360.5	253.7	21.6	403.6	244.6	NA
11-20	380.4	258.1	NA	404.3	268.9	NA
21-31	434.5	286.5	21.3	444.3	309.4	NA
June						
1-10	373.2	257.3	1.1	374.8	239.7	17.1
11-20	330.2	253.0	29.3	382.5	258.0	11.5
21-30	362.2	253.6	20.8	367.0	248.1	27.1
July						
1-10	335.9	294.3	26.3	357.3	243.7	30.2
11-20	339.8	245.3	42.6	333.5	225.4	39.1
21-31	358.5	261.9	89.2	343.5	234.4	86.5
August						
1-10	308.8	223.7	95.3	295.7	218.8	80.1
11-20	302.3	218.4	41.0	316.1	221.6	143.4
21-31	344.3	242.2	42.2	345.0	246.1	35.8
September						
1-10	315.3	217.7	17.2	315.6	216.9	45.0
11-20	326.9	224.2	41.8	324.9	223.5	14.2
21-30	333.3	225.7	16.9	335.1	218.0	16.6
October						
1-10	341.9	216.3	12.7	342.7	239.7	9.0
11-20	360.9	215.7	NA	366.5	241.5	NA
21-31	410.3	209.5	NA	402.8	239.8	NA

Source = Nigerian Meteorological Agency (NIMA) Katsina State, Nigeria
NA = Not Available

Table 4: Influence of biomass and nitrogen rate on harvest index of two maize varieties in 2014 and 2015

Treatment	**Harvest index**		
Biomass (B)	**2014**	**2015**	**Combined**
Control	18.1a	20.7b	19.4b
Albizia	20.9a	25.9a	23.4a
Parkia	19.4a	18.7b	19.0b
SE±	2.00	1.83	1.37
Nitrogen (N) Kg ha-^{1}			
0	20.4ab	22.5a	21.4a
40	23.4a	20.3a	21.9a
80	15.8b	22.7a	19.2a
120	18.4ab	21.6a	20.0a
SE±	2.27	2.25	1.62
Variety (V)			
DMR- ESR-7	21.5a	25.3a	23.4a
2009 EVAT	17.5a	18.3b	17.9b
SE±	1.61	1.47	1.10
Interaction			
B x N	S*	NS	NS
B x V	S*	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.

Table 5: Interaction between biomass and variety on harvest index (kg ha^{-1}) in combined analysis

	Variety	
Treatment	**DMR- ESR-7**	**2009 EVAT**
Biomass (B)		
Control	22.9a	16.0b
Albizia	24.8a	22.0a
Parkia	22.4a	15.7b
SE±	1.85	

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

Table 6: Interaction between variety and nitrogen rate on harvest index (kg ha^{-1}) in combined analysis

	Nitrogen (Kg ha-^{1})			
Treatment	**0**	**40**	**80**	**120**
Variety (V)				
DMR- ESR- 7	21.9^{ab}	25.1^{a}	22.4^{ab}	24.0^{a}
2009 EVAT	20.9^{ab}	18.6^{ab}	16.1^{b}	16.0^{b}
SE±		2.19		

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 is discovered to have low total nitrogen and organic carbon. The soil exchangeable basic cations follows this order: Ca>Mg>Na>K. The pH of the soil is acidic. The soil belongs to the textural class sandy loam (Oyebamiji *et al.,* 2017). The rainfall distribution was observed even in 2014, and this facilitated easy decomposition of organic material incorporated into the soil, thereby improved maize harvest index.

Albizia lebbeck amended plots was observed to perform better because of its better litter quality. Its materials contain higher average N content of 3.24 % N and 18.64 % C and lower average C: N ratio of 5.75 than *Parkia biglobosa* (Oyebamiji *et al.,* 2017) which facilitated its faster decomposition for nutrient release to the maize crop. It has been observed that litter decomposition is an important process that connects many aboveground and belowground processes; in that, the decomposition of dead leaves is one of the major pathways by which carbon (C) fixed during photosynthesis is returned to the atmosphere (Coûteaux *et al.*, 1995) and changed into soil organic matter. Therefore, rates of litter decomposition are a function of litter quality (e.g. N content, C/N ratio, lignin content etc) (Seastedt *et al.,* 1983; Meentemeyer, 1984).

Many studies (Gholz *et al.,* 2000; Silver and Miya, 2001) have concluded that the combination of climate (e.g. mean annual temperature (MAT), mean annual precipitation (MAP), actual evapotranspiration, etc) and litter quality (N content, C/N ratio, lignin content) are the primary factors controlling litter decomposition. Although the litter quality parameters of N content, C/N ratio and lignin contents have been commonly recognized as important variables of litter decomposition rates (Silver and Miya, 2001). Nitrogen content released from the two leguminous plants partly followed the same pattern as in decomposition for the first two weeks. Growth and yield increases as nitrogen are released from leguminous crops (Kang *et al.,* 1999; Mugendi *et al.,* 2000). Incorporation of *Albizia lebbeck* biomass caused increased harvest index than maize without incorporation of biomass (control). This increased harvest index was possible due to biomass incorporation which invariably contributed to significant increase observed in them (Abera *et al.,* 2005). This finding agrees with Lelei *et al.* (2009) who reported that the supply of N through mineralization of the high quality residue like *Albizia lebbeck* leads to higher maize yield.

Lack of maize fertilization tended to reduce maize yields. This agrees with Donovan and Casey (1998) who stated that the technologies that combine inorganic fertilizers with organic nutrient sources can be considered as better options in increasing fertilizer use efficiency, and providing a more balanced supply of nutrients for maize production. Also, the combination of organic and mineral fertilizer nutrient sources has been shown to result in synergistic effects and improved synchronization of nutrient release and uptake by crop according to Palm *et al.* (1997). This led to higher yields as the level of mineral fertilizer used was relatively low (that is, minimum of 40 kg N ha^{-1}). Response of maize to nitrogen application equally agrees with Daudu (2004) and Cherr *et al.* (2006) who reported that biomass used and the rate of nitrogen fertilizer applied has significant effect on maize growth. Incorporation of *Albizia lebbeck* with application of urea at about 40 kg N ha^{-1} rate or more improved the yield of both 2009 EVAT and DMR-ESR-7 maize varieties. *Albizia lebbeck* leafy biomass combined with inorganic fertilizer (urea) gave higher crop yields as compared to sole use of urea or sole *Albizia lebbeck* biomass (Mugendi *et al.,* 1999).

Conclusion

The soil is acidic in nature and has textural class sandy loam Therefore, incorporation of *A. lebbeck* into the soil decay rapidly and hence improved the soil quality for increased yield of maize. The use of plant biomass alone increase maize yield, but when combined in adequate proportion with nitrogen fertilizer, better yield of maize is the ultimate result.

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