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Effects of Organic and Mineral Fertilizer Inputs on Maize Yield and Soil Exchangeable Cations in Makera, Northwest, Nigeria

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Abstract
An experiment was setup in Makera in 2014 and 2015 cropping seasons toinvestigate the effects of different soil-incorporatedorganic manure and mineral fertilizer inputs on maize yield components, and soilexchangeable bases (cations).The experiments were laid out as 3 x 4 x 2 factorial in a split-split plot design with three replicates.Data were analysed using Analysis of Variance (ANOVA) at p =.05. *Albizialebbeck*biomass had higher mean values of N (3.24 %) and C (18.64 %)contents and lower mean value of C: N ratio (5.75) than *Parkia*. *Albizia*biomass significantly improved grain yield and harvest index than *Parkia*. Meanwhile, incorporation of biomass did not have significant effect on soil exchangeable sodium and potassium.It is therefore concluded that incorporation of *Albizia* with up to 120 kgNha^{-1} rate improved the yield components of both DMR-ESR-7 and 2009 EVAT maize varieties.

Keywords: Leguminous trees; biomass transfer; soil fertility; farmer; maize yield.

Introduction

Depletion of soil nutrient which arises from the continuous cultivation of soils without adequateaddition of external inputs is a major challenge inthe semi-arid areas of Nigeria.Leguminous trees that are nitrogen fixing trees are known to play 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). Cultivation of leguminous tree crops and biomass transfer is the main possibility for soil enrichment with nutrients, especially with nitrogen.The use of legume tree pruning as mulch in agroforestry system is a common practice to maintain soil organic matter and improve soil fertility in the tropics (Duguma*et al.* 1988).

The microbial decomposition of plant biomass in the soil depend on microbial population, soil temperature, soil aeration, soil water, soil pH and nature of the plant materials.The nature of plant materials is influenced by plant age, chemical composition, C/N ratios, and lignin and polyphenols content (Handayanto, 1997; Hartemink and O'Sullivan, 2001; Berge andMcClaugherty, 2002; Oladoye*et al.* 2005; Shimamoura andMomose, 2005). Although inorganic fertilizers would be the easiest way to overcome nutrient depletion Sanchez (2002), this product is not readily available for use by smallholder farmers. Even when they are available, their negative effects (such as erosion, leaching of nutrients etc.) on soil health and environment are of grievous consequences.

Technologies that combine mineral fertilizers with organic nutrient sources can be considered as better options in increasing fertilizer use efficiency, and providing a more balanced supply of nutrients (Donovan and Casey 1998). 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 (Palm *et al.* 1997) leading to higher yields; especially when the levels of mineral fertilizers used are relatively low (Kapkiyai *et al.* 1998).

Material and methods

Study area

The study area is Makera, a village in Dutsinma Local Government Area of Katsina State, having an area of 527 km², altitude of 605 m and a population of 169, 671 and is found within Latitude $12^0$27'18" N and Longitude $07^0$29'29"E. It is also found in the basement complex derived soils of Katsina State (Oguntoyinbo, 1983).

Experimental design

The experiments were laid in split-split plot design in 3 x 4 x 2 factorials with three replicates. The plot dimensions were 4 m x 3 m (12 m^2). Leafy biomass of *Albizia lebbeck* and *Parkia biglobosa* were pruned and incorporated fresh into the soil at the rate of 6 kg for each 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 seasons (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) were obtained from Katsina State Agricultural and Rural Development Authority (KTARDA). Two seedswere planted per hole at equal depth and it was later thinned to one 2 (WAP) by conventional spacing of 75 cm x 25 cm two weeks after incorporation of leafy biomass of *Albizia* and *Parkia* into the soil. The total maize population was 64 stands per plot.

Plant tissue analysis of agroforestry tree species

Samples of harvested 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 (Anderson and Ingram, 1993; Brandstreet, 1965). Lignin were determined by the Acid Detergent Fibre (ADF) method as outlined in (Anderson and Ingram, 1993). The polyphenol was extracted in hot (80^0C) 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 and these were also used to obtain yield data at harvest.

Statistical analysis

Data were analysed by subjecting 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

Table 1 shows some selected soil physical and chemical properties before the commencement of the experiment in 2014. The soil was low in total nitrogen and organic carbon with values of 0.04 % and 0.53 % respectively. The soil distribution of exchangeable basic cationsfollowed this order: Ca>Mg>Na>K. Nitrate-nitrogen was higher than ammonia-nitrogen in the soil. The soil was acidicand had loamy sand texture.

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

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
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})	
Na	0.35
K	0.20
Ca	6.25
Mg	1.01

There were differences in the chemical composition of *Albizia* and *Parkia* biomass as observed during 2014 and 2015cropping seasons. In comparison, the leaves of *Albizia* contained more N (leading to lower C: N ratio) than *Parkia*. *Albizia* had a higher concentration of lignin with mean value of 11.06, while *Parkia* had higher C: N ratios with mean value of 6.30. The result in Table 2 shows that *Parkia* had low N and C contents compared to *Albizia*. *Grain yield(kg ha^{-1})*

Plots amended with *Albizia* had significantly higher values of grain yield than other treatments with 2097.2kg $ha^{-1}$and 1666.7kg ha^{-1} for 2014 and 2015 cropping seasons respectively and an average value of 1881.9kg ha^{-1} for the two cropping seasons. For 2014 cropping season, the control treatment had significantly lower value (833.3kg ha^{-1}) of grain yield than plots amended with plant biomass and mineral fertilizer . No significant effect oftreatment on grain yield was observed in 2015. Grain yield was not significantly influenced by maize varieties (Table 3).

Table 2: Mean chemical composition of the leaf biomass of *Albizia lebbeck* and*Parkia biglobosa* in 2014 and 2015

Species	N %	C %	Lignin %	Polyphenol %	C: N
Albizialebbeck	3.24a	18.64a	11.06a	0.57b	5.75b
Parkiabiglobosa	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).

Table 3: Influence of biomass application and nitrogen rate on grain yield (kg ha^{-1})of two maize varieties in 2014 and 2015

	Grain yield (kg ha^{-1})		
Treatment	2014	2015	Combined
Biomass (B)			
Control	1388.9b	1395.8ab	1392.4b
Albizia	2097.2a	1666.7a	1881.9a
Parkia	1413.2b	930.6b	1171.9b
SE±	210.71	162.49	136.18
Nitrogen (N) Kgha-^{1}			
0	833.3b	990.7a	912.0b
40	1875.0a	1250.0a	1562.5a
80	1652.8a	1509.3a	1581.0a
120	2171.3a	1574.1a	1872.7a
SE±	221.33	201.49	152.62
Variety (V)			
DMR- ESR-7	1569.4a	1245.4a	1407.4a
2009 EVAT	1696.8a	1416.7a	1556.7a
SE±	180.69	147.99	117.56

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

Harvest index			
Treatment	2014	2015	Combined
Biomass (B)			
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

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

Harvest Index

Plots amended with *Albizia* had significantly higher value (25.9kg ha^{-1}) of harvest index than other treatments in 2015. 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 (23.4kg ha^{-1}) of harvest index than other treatments. In 2015, DMR-ESR-7 variety of maize had significantly higher value (25.3kg ha^{-1}) of harvest index than 2009 EVAT variety. No significant difference in harvest index was observed among varieties in 2014 (Table 4).

Soil Exchangeable Sodium (cmol kg^{-1})

In 2014 and 2015, control plots had significantly ($p < 0.05$) higher values (0.63kg ha^{-1}, 0.80 kg ha^{-1}respectively) ofsodium than in other treatments. In 2014, plots supplied with 120 kg N ha^{-1}had significantly higher value (0.49kg ha^{-1}), while plots supplied with 80 kg N ha^{-1} had significantly higher value (0.76kg ha^{-1}) of sodium than in all other treatments in 2015.

Soil Exchangeable Potassium (cmol kg^{-1})

In 2014 and 2015, control plots had significantly ($p < 0.05$) higher values (0.35kg ha^{-1}, 0.42kg ha^{-1} respectively) of potassium than other treatments. In 2014, plots supplied with 120 kg N ha^{-1}had significantly higher value (0.27kg ha^{-1}), while in 2015; plots supplied with 80 kg N ha^{-1} had significantly higher value (0.37kg ha^{-1}) of potassium than in all other treatments. In 2015, soils in which DMR-ESR-7 maize variety was cultivated had significantly higher value (0.35kg ha^{-1}) of potassium than soils in which 2009 EVAT maize variety was cultivated. No significant effect of maize varieties on soil potassium was observed in 2014 (Table 6).

Table 5: Influence of biomass application and nitrogen rate onsoil exchangeable Na (cmol kg^{-1})at maize harvest in 2014 and 2015

Treatment	Soil exchangeable Na (cmol kg^{-1})		
	2014	2015	Combined
Biomass (B)			
Control	0.63a	0.80a	0.71a
Albizia	0.27b	0.51b	0.39b
Parkia	0.24b	0.59b	0.42b
SE±	0.505	0.034	0.039
Nitrogen (N) Kgha-1			
0	0.44ab	0.62b	0.53a
40	0.36ab	0.60b	0.48a
80	0.24b	0.76a	0.50a
120	0.49a	0.57b	0.53a
SE±	0.072	0.047	0.055
Variety (V)			
DMR- ESR-7	0.39a	0.67a	0.53a
2009 EVAT	0.37a	0.60a	0.48a
SE±	0.064	0.036	0.039

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: Influence of biomass application and nitrogen rate onsoil exchangeable K (cmol kg^{-1})at maize harvest in 2014 and 2015

	Soil exchangeable K (cmol kg^{-1})		
Treatment	2014	2015	Combined
Biomass (B)			
Control	0.35a	0.42a	0.38a
Albizia	0.17b	0.25b	0.21b
Parkia	0.14b	0.29b	0.22b
SE±	0.025	0.017	0.018
Nitrogen (N) Kgha-^{1}			
0	0.25ab	0.31b	0.28a
40	0.21ab	0.30b	0.25a
80	0.15b	0.37a	0.26a
120	0.27a	0.32ab	0.29a
SE±	0.038	0.026	0.027
Variety (V)			
DMR- ESR-7	0.22a	0.35a	0.29a
2009 EVAT	0.21a	0.29b	0.25a
SE±	0.032	0.018	0.019

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 of the experimental site was basically sandy loam and acidic with pH of 4.10. *Albizia* amended plots performed better as a result of its plant residue quality. *Albizia* contained higher average content of 3.24 % N and 18.64 % C and lower average C: N ratio of 5.75 than *Parkia.* The report of Giller and Wilson (1991) and Oyebamiji *et al.*(2017) revealed that plant residues with a smaller C: N (< 30:1) is liable to decompose more rapidly with a net mineralization of N after incorporation into the soil. Hence, N is rapidly released and made readily available for crops; and by comparison *Albizia* biomass decomposed and mineralised more rapidly than *Parkia.*

The general performance of maize plants was higher in *Albizia* amended plots. Incorporation of biomass caused increased grain yield and harvest index of maize than control.Application of N from 40 $kgNha^{-1}$ to 120 $kgNha^{-1}$ had an increasing effect on grain yield. This agrees with Buah *et al.*(2009) who reported that 120 $kgNha^{-1}$ currently produced higher grain yield of maize in the semi-arid, Nigeria. It was also reported by Dakora and Philips (2002) and Cheng *et al.*(2004) that biomass may take up higher amount of base cations which in turn cause the soil to be acidic. Adeboye *et al.*(2005) also reported that exchangeable cation reduction in the soil could lead to lowering of the soil pH.

It was observed that soil content of sodium and potassium had no effect on assessed crop yield components, this could mean that the soil had sufficient content of these mineral nutrients that can sustain the growth and the yield of the maize without fertilizer application whether organic or inorganic. This also shows that, nitrogen application did not affect soil exchangeable sodium and potassium because, they are mobile especially in sandy soil, and so they can be leached, eroded and washed away, or rather been used up as observed by Abril and Roca (2008).

Conclusion

The soil texture was generally sandy loam and acidic in nature. *Albizia* biomass significantly affected grain yield and harvest index, but this was not the case with soil exchangeable sodium and potassium. Application of N fertilizer did not affect maize grain yield, harvest index, soil exchangeable sodium and potassium. DMR-ESR-7 maize variety performed better than variety 2009 EVAT in harvest index yield component.

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