Integrated management of soil and water resources using biochar technology: The Nigeria experience

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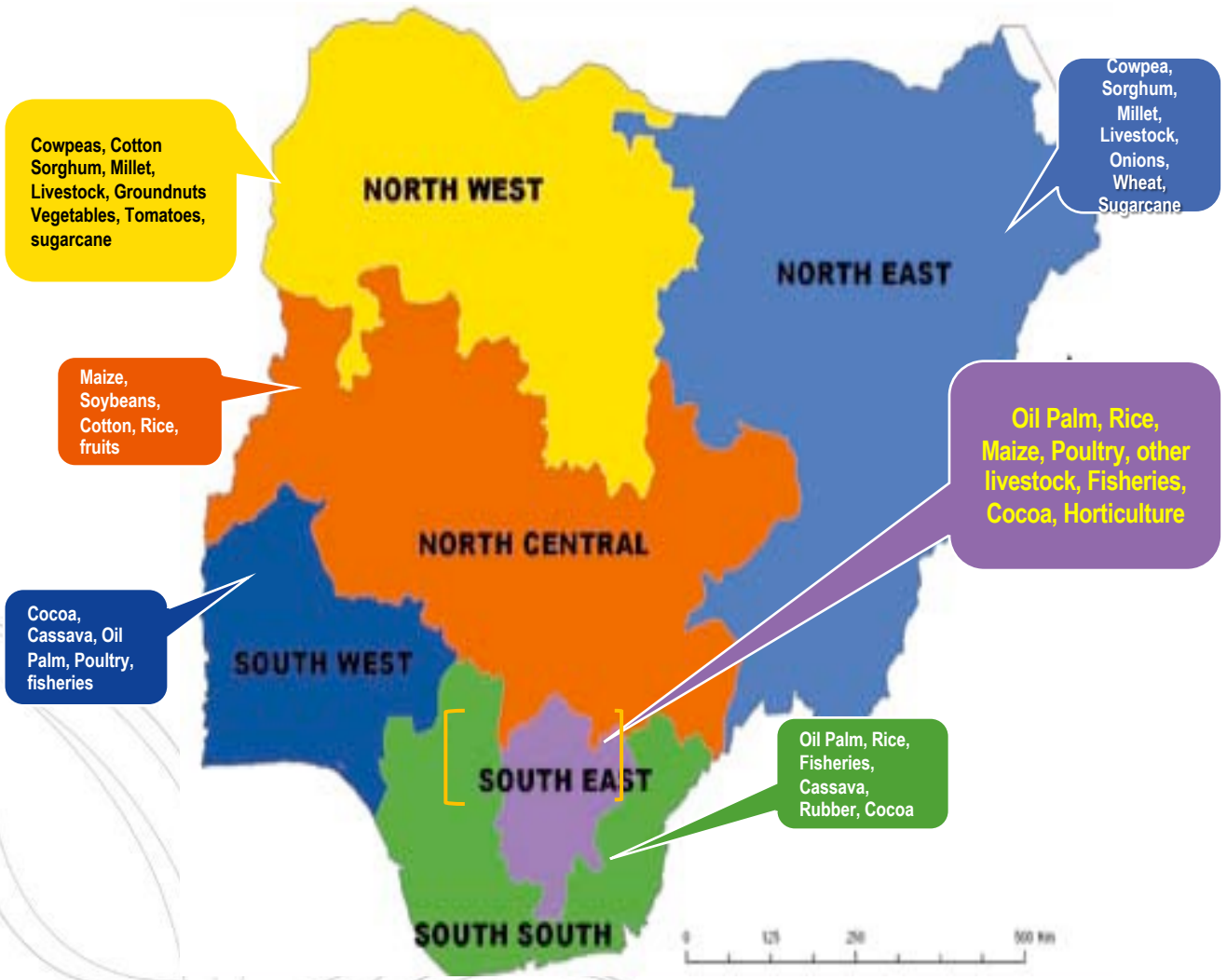
INTRODUCTION

- Nigeria is a well-endowed country
- Agro-ecological potentials capable of supporting all types of crops, animal species, poultry types, fishes and allied organisms for human nutrition and agro-allied industries;
- 3.14 million Ha of irrigable area (0.22 million ha now utilized);
- 267 billion cubic metres of surface water;
- 57.9 billion m^3 of underground water;
- 37 billion m^3 stored in dams.
- Rainfall regime of 300 to 4,000 mm per annum.
- Properly harnessed, the nation should not be in want agriculturally,

Agricultural Value Chain In NIGERIA



- **80% (739,000 Km^2)** of Nigeria's land is arable while only about **33% (243 Km^2)** is presently being cultivated.
- The sector provides employment for **70%** of the population who mostly operate on small scale, with little or no access to finance, technology and capacity building
- Nigeria's food production growth rate is **2.5%** while food demand increases at **3.5%** due to population growth

NG Cropland Stats Across Regions

Agricultural Zone	Total Area [sq. km]	Estimated Cropland Percentage [%]	Cropland Area [sq. km]
North East	278,472.42	49.38	137,504.84
North Central	227,968.82	55.66	126,895.84
North West	214,340.87	65.35	140,080.54
South East	28,515.81	40.95	11,677.02
South South	83,847.40	24.00	20,125.67
South West	76,315.36	28.62	21,840.87
Nigeria Total Area [sq. km]	909,460.67		
Cropland Total Area [sq. km]	458,124.78		

Chemical composition of Nigerian soils.

- Most proportion of soils in tropical Africa are described as low-activity-clay (LAC) soils with cation exchange capacity (CEC) usually less than 20cmol kg^{-1} and having very low plant nutrient reserves in the form of un-weathered primary minerals.
- Nigerian soils are generally light textured and low in clay content with a range of 9 to 43%;
- in more than 60% of the area, clay content is less than 15%.
- Soil reaction (pH) ranges from 4.2 to 8.5;
- Combined calcium (Ca) and magnesium (Mg) content varies from 0.5 to 5.55 cmol Kg^{-1};
- Organic matter content also varies from 1.0 to 2.55%

Need for Biochar technology

- Biochar technology has promise for:
  - Sustainable soil productivity and crop production,
  - Improvement of health and meat quantity and quality of livestock,
  - Increase in fish growth performance and carcass quality,
  - Climate change mitigation &
  - Cleaner Environment

- Biochar technology is capable of replacing the inefficient centuries-old slash-and-burn agriculture.

- It helps to transform agriculture from being part of the problem of GHGs generation to being part of the solution.

- Greatest potential of biochar is for the highly weathered tropical soils which have been described as the most depleted soils in the world (IFDC, 2012) (due to dominance of LAC, low nutrient content, low SOM, low CEC).

WHAT IS BIOCHAR ?

❖Biochar is the carbon-rich product that remains when biomass is heated to high temperature bellow 1000^{O}C in reduced oxygen conditions(Lehmann and Joseph, 2009).

- Therefore, both charcoal and biochar are the same, except that biochar product is created for use as a soil amendment.

- Pyrolysis of biomass produces three items : biochar, bio-oils and syngases (Lehmann, 2007).

Biochar

- Biomass deliberately charred and applied to soil -- *Biochar*

BIOCHAR FOR SOIL FERTILITY IMPROVEMENT

- Studies conducted (Steinar et al., 2011; Zeelie, 2012 and Ndor et al., 2014, Ndor et al., 2015, Ndor et al., 2016 and Joseph et al.,2021) have shown that biochar can aid in soil quality improvement and increase crops yield.

HOW :

- Improved cation exchange capacity in the soil,
- Decrease soil acidity,
- Improve soil structure,
- Improved plant nutrient use efficiency,
- Improved water-holding capacity,
- Soil remediation of heavy metals,
- Increase crop growth and yield
- Increase activities of micro-organism in the soil.

Detailed meta-analysis of the peer review research has shown that biochar

1. Increases average crop yield by 10-42% with biochar addition,
2. The greatest increases in yield are in low-nutrient P-sorbing acidic soils (common in the tropics) and in sandy soils in drylands due to increase in nutrient retention and water holding capacity.
3. It has also shown that biochar can increase P availability by 4.6 times,
4. The effect on yield, plant resistance to disease and soil properties is a function of dose (Inverted U shape/Biphasic), feedstock and final temperature of biochar production.
5. Adding small amounts of treated biochar in the rhizosphere every season will result in a continued increase in soil carbon, plant growth and other beneficial soil properties and an increase in farmer profitability

Joseph, S., Cowie, A.L., Van Zwieten, 2021. How biochar works, and when it doesn't: A review of mechanisms controlling soil and plant responses to biochar. *GCB Bioenergy*. 00:1–34

1. On average; decrease plant tissue concentration of heavy metals by 17-39%
2. Reduce non-CO_2 greenhouse gas emissions from soil by 12-50%.
3. Enhancing biomass with minerals and them pyrolyzing or adding minerals and organic compounds to biochar can enhance the biochars properties.
4. Biochar catalyzes microbial and chemical processes in the rhizosphere, decreasing the activation energy for biotic and abiotic reactions, which can increase nutrient mineralization and facilitate nutrient uptake by plants.
5. It can act as a microbial fuel cell where there is growth of beneficial micro-organisms, production and consumption of electrons, fixation of carbon and nitrogen from the soil and the air;

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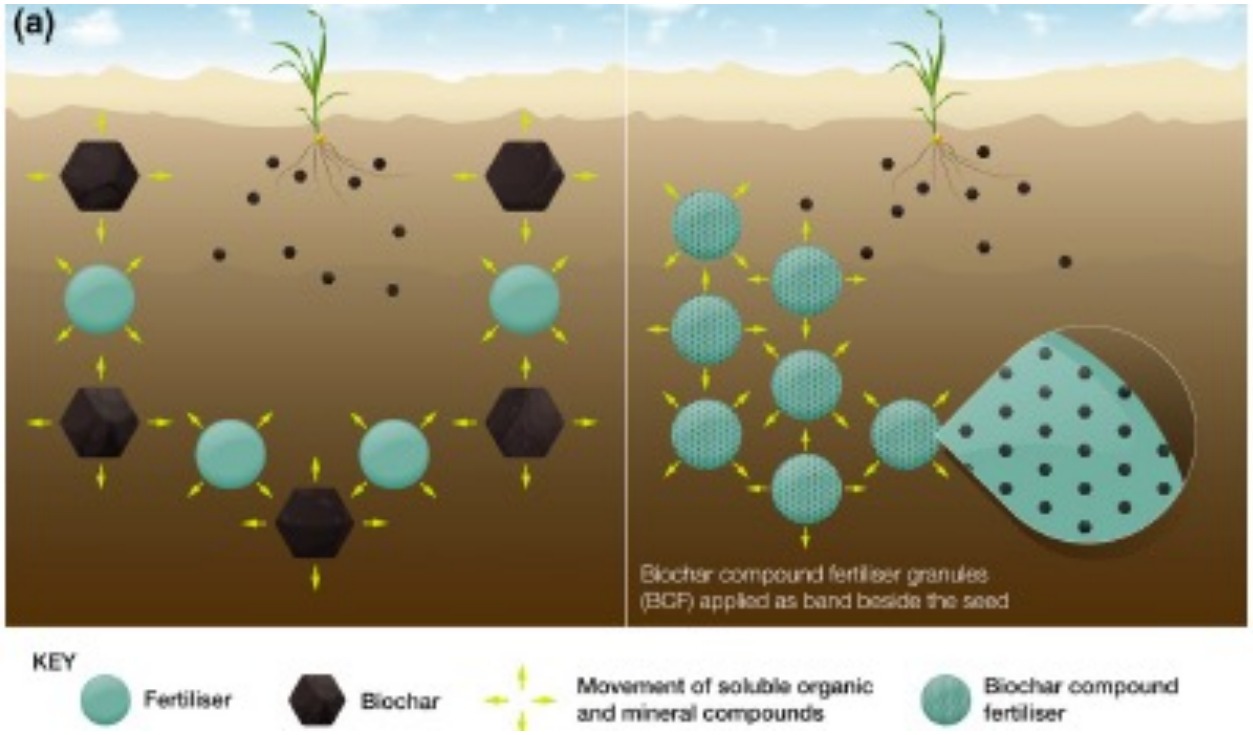
An Understanding of How Biochar Works or Doesn't Work

Germination and Early Growth Stage

Biochar (BC + F) with separate fertilizer applied at high application rates;

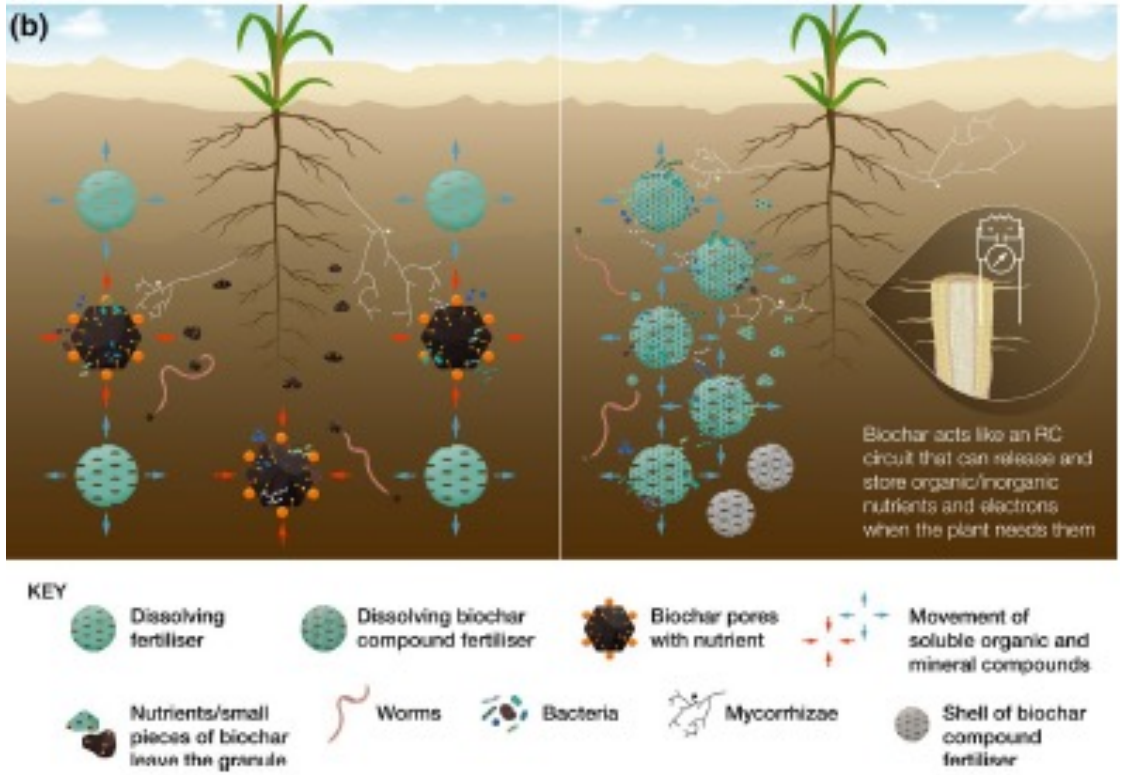
Biochar incorporated into fertilizer (BCF) applied at low application rates;



Growth Stage and Harvesting

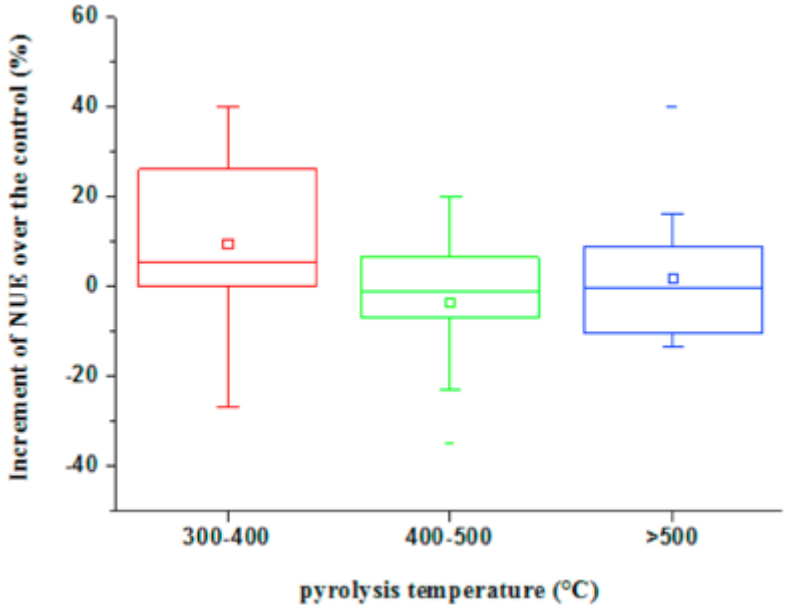
BC + F

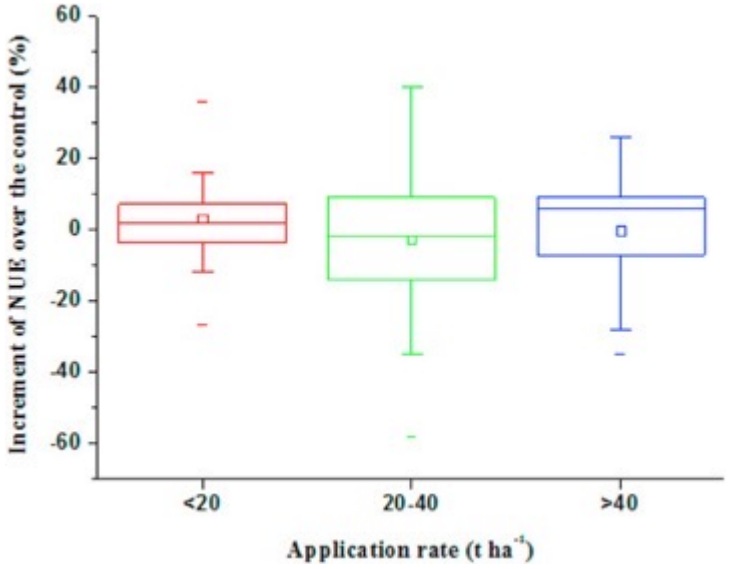
BCF

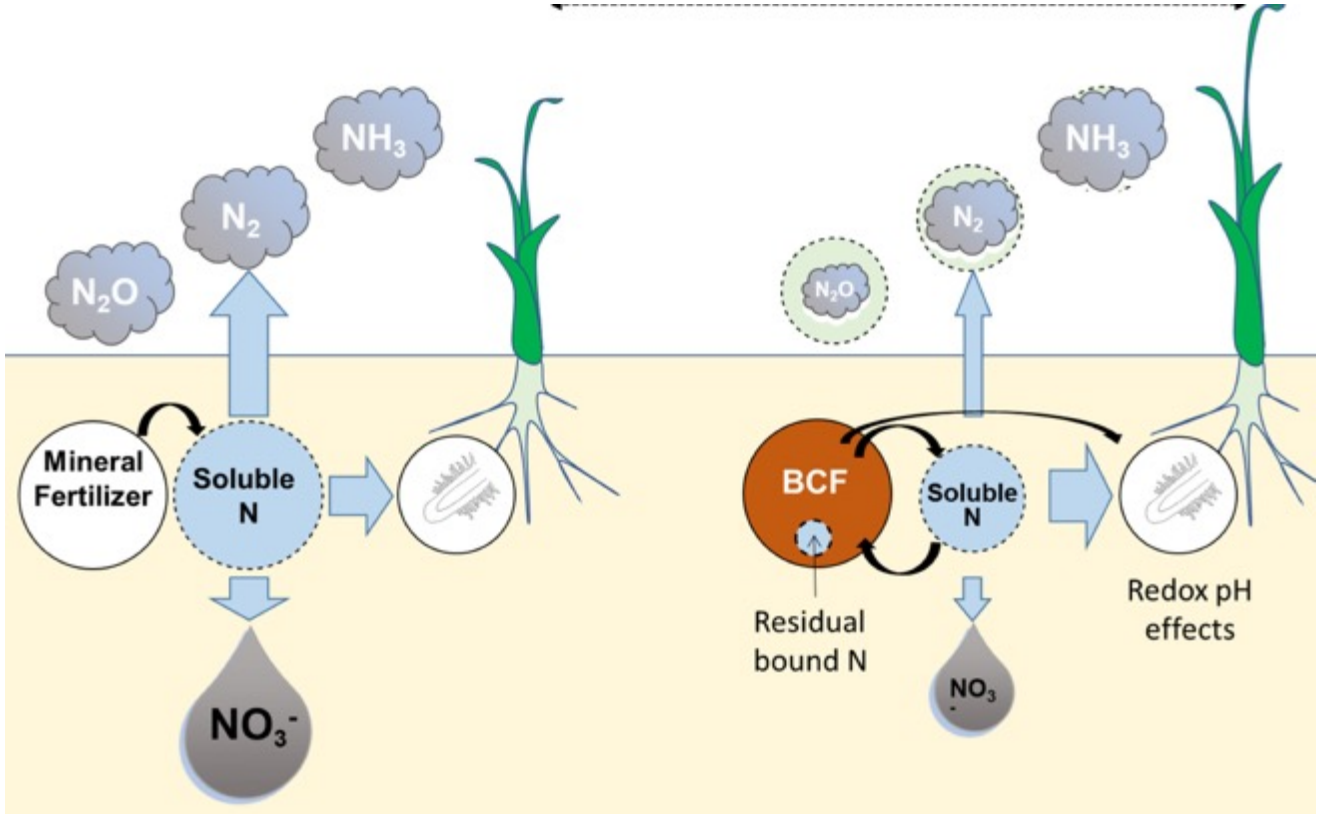


Joseph et al 2021 How biochar works, and when it doesn't: A review of mechanisms controlling soil and plant responses to biochar. *GCB Bioenergy*. 00:1–34

Biochar by Itself Does Increase Nitrogen Use Efficiency (NUE)







Mixing 25% biochar with chemical fertilisers to produce a Biochar compound fertilizer (BCF) yield increases can be as high as 30% but typically 15%. Partly due to reduce N emissions and leaching; Figure courtesy Daniel Rasse et

Ahmed et al. 2021 Biochar modulates mineral nitrogen dynamics in soil and terrestrial ecosystems: A critical review Volume 278, 130378

EFFECT OF BIOCHAR ON DEGRADED SOIL OF COLLEGE OF AGRIC. LAFIA, NIGERIA

Treatment	pH ratio		(%)		(ppm)	(Cmol/kg)					
Biochar (t/ha)	H_2O	0.01 $CaCl_2$	OC	TN	Av. P	Ca	Mg	K	Na	H+Al (Acidity)	CEC
0	6.25	5.54	0.37	0.18	14.16	4.43	1.00	0.70	0.45	0.59	6.51
5	6.65	5.77	0.44	0.37	12.61	4.22	1.22	0.86	0.41	0.48	6.25
10	6.91	5.83	0.56	0.38	13.37	6.34	2.50	1.59	0.42	0.43	11.35
LSD(0.05)	0.38	0.17	0.03	0.04	0.51	0.57	0.46	0.46	0.04	0.03	0.34
S.E.M	0.13	0.06	0.03	0.01	0.18	0.21	0.17	0.16	0.16	0.01	0.12

LSD= least significant difference; S.E.M= Standard error of mean

BIOCHAR FOR SOIL FERTILITY IMPROVEMENT, LAFIA, NIGERIA

Treatment	Particle distribution (%)				% Org.	Bulk density	% porosity
Biochar(t/ha)	Sand	Clay	Silt	Tex. class	matter	(g/cm^3)	
0	87.33	6.33	6.33	Sand	0.67	1.67	36.61
5	87.00	7.67	6.33	Sand	0.76	1.63	38.44
10	85.33	7.67	7.67	Sand	0.96	1.61	39.63
LSD(0.05)	2.51	1.51	1.51		0.03	0.03	0.06
SEM	0.54	0.54	0.54		0.01	0.01	0.23

LSD= Least significant difference S.E.M= standard error of mean

EFFECT OF BIOCHAR ON NUTRIENT UPTAKE OF MAIZE IN LAFIA

Treatments	MACRO-NUTRIENTS(NPK) UPTAKE OF MAIZE					
(Biochars)	(%) N	*(%) N	(mgkg) P	(*mgkg) P	(Cmol/kg) K	*(Cmol/kg) K
RH(g/pot)						
0	1.44	0.12	40.61	3.25	3.90	0.25
60	1.98	0.54	42.92	6.23	3.95	0.31
120	2.87	0.72	63.12	7.12	5.74	0.52
LSD(0.05)	0.45	0.32	7.47	1.58	0.76	0.21
SD(g/pot)						
0	1.44	0.13	33.41	2.76	2.86	0.21
60	2.25	0.49	51.60	6.53	4.74	0.42
120	2.92	0.76	61.73	7.12	6.00	0.68
LSD(0.05)	0.45	0.32	7.47	1.58	0.76	0.21

Treatment (Biochars)	Number of pods/plant		Fresh pod weight/plant		Seed weight/ plant(g)		Seed weight/ plot(kg)		Seed weight t/ha	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Sawdust(t/ha)										
0	49.32	54.52	32.23	34.10	4.06	4.49	1.09	1.01	0.64	0.63
5	52.42	56.81	36.96	38.42	4.91	4.97	1.30	1.23	0.83	0.77
10	68.00	71.82	39.10	39.93	5.27	5.78	1.49	1.34	0.93	0.82
Rice husk(t/ha)										
0	53.12	55.34	34.82	33.85	3.84	4.48	0.92	0.90	0.59	0.60
5	58.81	61.53	35.56	35.53	4.89	4.93	1.17	1.18	0.73	0.75
10	63.14	75.85	40.18	43.23	6.06	6.12	1.48	1.46	0.90	0.95
LSD(0.05)	10.94	10.85	4.95	3.42	1.07	1.27	0.21	0.30	0.11	0.12
Sesame varieties										
Local	55.72	59.32	35.05	37.12	4.75	4.77	1.14	1.13	0.72	0.71
Yandev 55	56.87	62.01	37.51	37.83	5.06	5.21	1.24	1.23	0.76	0.77
LSD(0.05)	0.93	0.50	0.85	0.24	0.18	0.13	0.06	0.10	0.02	0.04
Interaction										
SDB X RHB	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

RHB= Ricehusk Biochar; SDB=Sawdust Biochar; NS= Not significant

HOW DOES IT HAPPENED

- Biochar has little plant nutrient content itself but acts more as a soil conditioner by making nutrients more available to plants(Ndor et al 2015)

- Biochars can be beneficial to acidic soils, acting as a liming agents because of the ashes that increases soil pH, (Ndor et al. 2014).

- Biochar modify the soil's pore system into micro-pores especially in sandy soil; that is the reason behind increased in water holding capacity of soil amended with biochar (Ndor et al, 2016)

- The large surface area of biochar may results in increased CEC, which may prevent nutrient from leaching (Ndor et at, 2015).
- Biochar can improve root growth and thereby stimulate aggregation and also enhanced microbial activity (especially rhizopheric bacteria and mycorrhizal fungi, which are in direct association with roots and form a more extensive rooting system *via* filaments know as mycelia and hyphae). (Zeelie, 2012).

- The large surface area and pore structure of biochar likely provides a habitat for soil microorganisms, which in turn may aid in making some nutrients available to crops.(Steiner, 2007)

GCRF-3 NUTRICHAR Nigeria

NUTRICHAR™

Pot Trials of a locally-produced Biofertiliser

PyroGenesys
All things work together for good

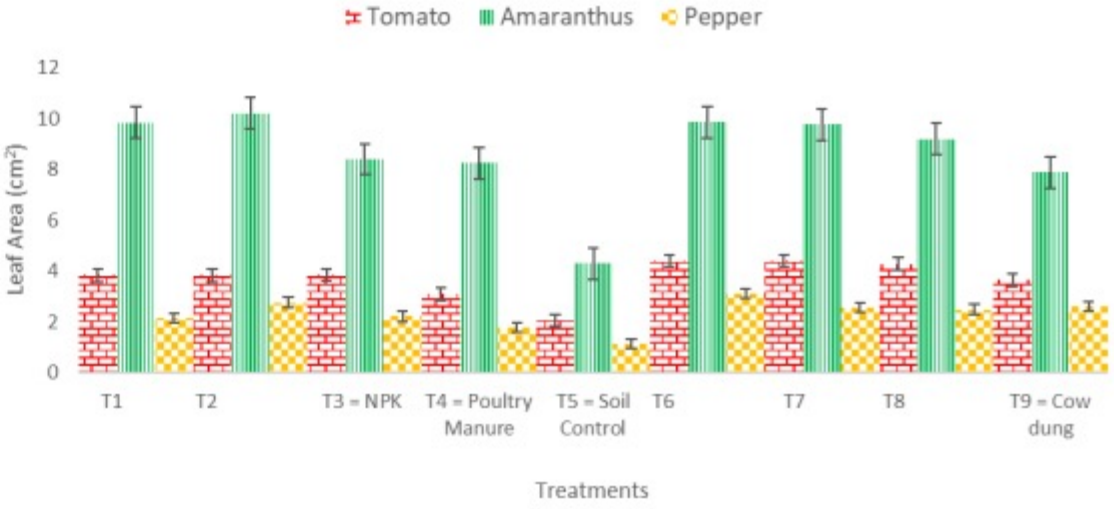
Nasarawa State University, Keffi

AIM: Compare performance of Biochar formulations to no fertiliser, inorganic NPK, cow & poultry manure.

ACHIEVEMENTS:

1. NUTRICHAR™ outperformed inorganic NPK, cow & poultry manure fertilisers.
2. NUTRICHAR™ can be locally produced from underutilised agricultural waste residues.
3. Significant knowledge transfer took place between both partners
4. Plans for further collaboration are being developed

Screenhouse Pot Trials



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