

PRODUCTIVITY OF STRIGA INFESTED MAIZE (*ZEA MAYS* L.) UNDER BIOCHAR-FERTILIZER MIXTURE FOR SUSTAINABLE FOOD SECURITY IN THE SUDAN SAVANNAH OF NIGERIA

**N. MUNKAILA¹, M. A. YAWALE², I. SALISU³, M. S. GARKO¹, A. M. SAAD²,
AND I. A. Madu²**

¹*Department of Crop Science Sule Lamido University, Kafin Hausa Jigawa State*

²*Department of Crop Science, Aliko Dangote University of Science and Technology Wudil*

³*National Examination Council*

*Corresponding Author: - munkailanasir09@gmail.com / msanigarko11@gmail.com
(+234 813 2539 187) / (+234 806 5576 161)*

Abstract

An experiment was conducted in 2024 rainy season concurrently at two different locations (Bayero University Kano [11^o 98' 23" N; 8.43'02" E] and Irrigation Research Station Kadawa [11^o38' 45" N, 8^o26' 52" E] both in Kano State within the Sudan savanna zone of Nigeria. The objectives of the study were to evaluate the effect of Biochar and fertilizers on striga infestation and productivity of maize for sustainable food security. The experiment consisted of 13 treatments combination, and using two levels each of biochar (B), N, P and K alone and in combination to give 13 treatments while zero (0) application was used as control. The experiment was laid out in a Randomize Complete Block Design (RCBD) and replicated three times. The result indicates that application of 60:30:30 Kg^{ha}⁻¹ NPK plus 2 tha⁻¹ biochar gave better weed suppression and higher grain yield as comparable to the recommended rate of both NPK and biochar and is therefore recommended for sustainable food production in the study areas, as they suppress weed infestation and gave higher growth and yield in maize.

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops worldwide. It belongs to the grass family *Poaceae*. It is highly productive and adapts to a wide range of agro-ecological zones (Babatunde *et al.*, 2008). As the world best adapted crop, maize is grown between latitude 58°N and 40°S of the equator. Conversely, the lower prevailing temperatures at higher altitudes retard growth and extend the time taken to reach maturity (Anonymous, 2016). In general, maize needs at least 400-1000 mm of well distributed rainfall during growing season if the soil texture is good enough to hold moisture for optimum crop absorption and utilization (Lafitte, 2012).

The world maize production ranking for year 2024 shows that Nigeria ranked 14th position producing 10.4 million metric tonnes (FAO, 2024). In 2024, maize production for Nigeria was 10.4 million tonnes though Nigerian maize production fluctuated substantially. An estimated 951,625,000 metric tonnes of maize was produced globally of which Nigeria contributed 10.4 million metric tonnes making it the second largest producer in Africa after South Africa (FAO, 2024).

Maize is high yielding, easy to process and easily digested. It is a versatile crop, growing across a range of agro-ecological zones (IITA, 2009). Every part of maize has economic values, the grains, leaves, stalk, tassels, and cob which can all be used to produce a large variety of food and non-food products. In advanced countries, it is an important source of many industrial products such as corn sugar, corn oil, corn flour, starch, syrup, brewers grit, salad, soap making, lubrication and alcohol (Dutt, 2005).

Biochar is a charcoal like material used as a soil amendment. Biochar is a stable soil material rich in carbon and can endure in the soil for thousands of years. Biochar is made from biomass through pyrolysis and this make it a valuable soil amendment material. The 2000 years old practice convert agricultural waste into soil enhancer that can hold carbon, boost food security and increase soil biodiversity and discourage deforestation. Biochar depending on properties can remain in the soil for greater than 1000 years (Skjemstead *et al.*, 2004). The carbon in biochar is chemically and biologically more stable than the carbon in the plant residue from which it is made. This make it difficult to break down and, in some cases, biochar carbon has been known to remain soil conditioner for hundreds or even thousands of years (Ngwu, 2012).

Fertilizer application and continued used of only major element (N.P.K) without taking biomass especially biochar into vital consideration contribute to low maize yield. Soil nutrient balance studies have shown depletion of soil nutrient as one of the most important constraint to sustainable agriculture in savanna areas of Nigeria (Rego *et al.*, 2002). However, researchers in various locations in Nigerian savanna have observed that the application of biochar and fertilizers, coupled with current intensive use of land could lead to high maize crop response (Clough *et al.*, 2013).

Biochar has the ability to hold nutrients in the soil and release them to the crop only at the time of need as well as the ability to increase soil fertility through its carbon sequestration potential, water conservation, add Ca, Mg and Mn into the soil as well as its ability to prevent weed seeds like striga seeds from germinating (Weber *et al.*, 2009). Therefore, adoption of this technology of application of biochar and inorganic fertilizer may improve maize yield better than using inorganic fertilizers alone. It is also unfortunate that currently, a single dose rate recommendation for biochar is given as 2 t/ha for the entire region of West Africa instead of site-specific recommendation. More importantly, farmers find it difficult to apply recommended rates of inorganic fertilizer to their crops due to high cost of the fertilizer. Therefore, application of biochar and inorganic fertilizer either in half dose or full doses may solve the problem of inadequate nutrient supply to the crop. The objectives of this study were to: -

- i. Determine the best biochar-fertilizers combination rates for higher productivity of maize.
- ii. Evaluate the effect of biochar and fertilizers mixture on striga infestation of maize crop

Materials and Methods

Experimental Site

The research was conducted at the Bayero University Teaching and Research Farm of the Faculty of Agriculture Centre for Dry land Agriculture Farm (CDA) which lies on latitude 11°58'N and longitude 8°25' E, 457 m above sea level, and at the Irrigation Research Station/Institutes for Agricultural Research Kadawa both in Kano State of Nigeria during the rainy season of 2024.

Treatment and Experimental Design

The experiment consisted of 13 treatments combination by the use of two levels each of biochar (B), N, P and K alone and in combination to give 12 treatments while zero application was used as control. The two rates are the recommended of biochar at 2 t ha⁻¹, NPK at 120:60:60 Kg ha⁻¹ respectively, and half of the recommended rate of biochar at 1 t ha⁻¹, NPK at 60-30-30 Kg ha⁻¹. The experiment was laid out in a Randomize Complete Block Design (RCBD) and replicated three times.

Experimental Materials

Rice bran biomass was the source of the biochar while, urea, single super phosphate (SSP) and muriate of potash (MOP) was used as the sources of N, P and K, respectively. The maize variety used was **SAMMAZ-34**, it is an early maturing variety, which matures in 75 days. It is non-tillering, erect and with potential yield of 4 - 7 t ha⁻¹. The Striga seed (500 g) was mixed with 1 kg of fine sand to constitute the inoculums, 10 g of the mixture was inoculated per planting hole during the planting of the maize.

The biochar was prepared; a metal drum was used. The drum was perforated with holes at the sides. The drum was surrounded with the rice bran (Biomass) and the fire was set in it using firewood. The biomass was covered with Zinc sheets to allow limited oxygen during the burning. It was allowed to burn at 400°C until it forms biochar. Once done, the fire was quenched using water after which the carbonized material was spread on the floor and allowed to cool for one hour. Care was taken to ensure that the biomass does not burn longer than necessary to avoid turning into ash.

Data Collection

Striga Count

The number of emerged striga shoot was counted from randomly selected tagged five plants in the net plot at 6,9 and 12 weeks after sowing and the average was computed to express the striga count per plant.

Weed Dry Weight

A 1m² quadrat was thrown randomly and fresh weight samples were collected per treatment plot at 3, 6 and 9 WAS. The samples were cleaned and oven dried to a constant weight at a temperature of 70 °C for 48 hours. The weight was taken by weighing on a Mettler balance. This was expressed in Kg ha⁻¹ on cumulative basis.

Plant Height (CM)

Five plants were randomly tagged from each plot and their height was measured from the ground level of each plant to the topmost flag leaf and also to the tip of the tassel when they had produced tassels at 6 ,9 and 12 weeks after sowing(WAS) using meter rule. Their heights were added and average height per plant was computed.

Leaf Area Index (LAI)

The leaf area index which is the total leaf area divided by the land area was taken using specialise leaf area index meter called P-P50 leaf area index spectrometer on the field which gives the LAI values directly on the field.

Cob weight per plant (G)

Cobs from the five randomly tagged plants were weighed using a Mettler balance (Mettler Toledo SB 16001) and the means was recorded.

Grain Yield (Kg ha⁻¹)

The harvested cobs from each net plot were shelled, winnowed in the air to remove chaff and weighed in Mettler Balance. The weight was expressed in Kg ha⁻¹

Data Analysis

Data collected were subjected to analysis of variance using the general linear model in SAS (SAS, 2004). The treatment means were compared using Duncan Multiple Range Test DMRT (Duncan, 1955)

Results and Discussion

Striga Count

The significant effect of biochar and fertilizer on striga count of maize at both locations is shown in Table 1. Biochar application significantly influenced the striga count at the two locations. At CDA, during 6 and 9 WAS, maize plots without biochar had a significantly higher striga count compared to those treated with biochar, which were statistically similar. At 12 WAS, the control plots exhibited a significantly higher striga count than maize plots treated with 1 tonne per hectare (tha^{-1}) of biochar, while the lowest striga count was observed in plots treated with 2 tha^{-1} of biochar. At Kadawa, at 12 WAS, plots without biochar application had a significantly higher striga count than those treated with 2 tha^{-1} of biochar. However, the striga count in plots treated with 1 tha^{-1} of biochar was statistically similar to that of the untreated plots.

Fertilizer application also had a significant effect on striga count at both locations. At 6 WAS at CDA and 12 WAS at Kadawa, the control plots had a significantly higher striga count than fertilized plots, except for those where phosphorus and potassium were applied at 60 kg/ha, which were statistically similar. Other fertilizer treatments produced statistically comparable striga count. At 9 WAS at CDA, the control plots had significantly higher striga count than fertilized plots. However, the lowest striga count was recorded in plots where NPK was applied at a rate of 120:60:60, which was statistically similar to nitrogen applications at 120 and 60 kgha^{-1} and phosphorus and potassium applications at 60 Kgha^{-1} . At 12 WAS at CDA, plots treated with nitrogen at 60 Kgha^{-1} , phosphorus, potassium, and control plots had statistically similar striga count but these were significantly higher than those in plots treated with NPK at 120:60:60. The latter was statistically at par with NPK 60:30:30 and nitrogen at 60 kg/ha. No significant interactions were observed between biochar and fertilizer application across all sampling periods and locations.

Table 1: Response of Biochar and Fertilizer Rates on Striga count of Striga Infested Maize at CDA and Kadawa during 2024 Rainy Season

Treatment	Striga count					
	BUK/CDA			KADAWA		
Biochar (B)	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
1 tha^{-1}	2.42b	2.89a	2.63a	2.61	2.89a	2.56ab
2 tha^{-1}	2.53a	2.65b	1.79b	2.39	2.28b	2.28b
SE \pm	0.019	0.269	0.201	0.296	0.362	0.169
Fertilizer (F) (kgha^{-1})						
NPK	2.17b	2.00c	1.83b	2.83	1.67	2.00b
120:60:60						
NPK 60:30:30	2.50b	3.67b	2.42ab	2.00	3.00	3.00ab
Nitrogen 120	2.00b	3.00bc	2.50ab	2.17	2.50	2.33ab
Nitrogen 60	2.50b	2.33bc	2.75a	1.83	2.33	2.00b
Phosphorus 60	2.83ab	2.50bc	2.75a	3.17	2.67	2.50ab
Potassium 60	2.83ab	3.17bc	3.00a	3.00	3.33	2.67ab
Control	4.67a	5.67a	3.00a	2.67	3.67	3.33a
SE \pm	2.196	1.312	0.348	0.513	0.626	0.292
Interaction						
BXF	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within same column are not different statistically at $P=0.05$ level of probability using DMRT. NS= Not significant

Weed Dry Weight

The effects of biochar and fertilizer on weed dry weight of maize at CDA and Kadawa are shown in Table 2. The effect of biochar on weed dry weight was significant only at Kadawa, at 6 and 12 WAS, the control plots had significantly higher weed dry weight than those treated with 1 tha^{-1} of biochar, but this was statistically similar to plots treated with 2 tha^{-1} of biochar. At 9 WAS, the control plots had a significantly higher weed dry weight than biochar-treated maize plots, though no statistical difference was observed between 1 tha^{-1} and 2 tha^{-1} biochar applications.

Fertilizer application significantly affected weed dry weight at 9 and 12 WAS at Kadawa. The control plots had significantly heavier weed dry weight than those treated with full-dose NPK and full or half doses of nitrogen. However, weed dry weight in control plots was statistically similar to that in plots treated with phosphorus and potassium at 60 kg/ha and half-dose NPK.

No significant interactions between biochar and fertilizer application were observed at any sampling period or location.

Table 2: Response of Biochar and Fertilizer Rates on Weed Dry Weight of Striga Infested Maize at CDA and Kadawa During 2024 Rainy Season.

Treatment	Weed Dry Weight (g)					
	BUK/CDA			KADAWA		
Biochar (B)	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
1 tha^{-1}	5.10	18.84	10.55	15.69b	16.18b	25.48b
2 tha^{-1}	6.22	11.58	13.15	17.58ab	13.43b	28.36ab
SE \pm	0.846	2.514	1.474	2.768	3.994	4.630
Fertilizer (F) (kg ha^{-1})						
NPK	3.18	12.78	13.00	17.50b	11.50b	18.80b
120:60:60						
NPK	4.50	15.15	8.07	19.17b	24.92ab	38.80ab
60:30:30						
Nitrogen 120	5.92	19.68	15.20	15.90b	9.17b	17.75b
Nitrogen 60	7.34	18.73	12.17	15.97b	7.75b	19.08b
Phosphorus	5.13	7.42	11.18	13.42b	16.65ab	41.07ab
60						
Potassium 60	7.67	18.72	11.07	17.87b	18.85ab	26.00ab
Control	5.63	10.70	7.20	29.08a	38.20a	49.27a
SE \pm	1.465	4.355	2.553	4.795	6.917	8.020
Interaction						
BXF	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within same column are not different statistically at $P=0.05$ level of probability using DMRT. NS= Not significant

Plant Height

The significant effect of biochar and fertilizer on plant height of maize at both locations are shown in Table 3. Biochar application significantly affected maize plant height at Kadawa at 6 and 12 weeks after sowing (WAS). Maize plots treated with 1 tha^{-1} and 2 tha^{-1} of biochar had statistically similar plant heights, but these were significantly taller than those in the control plots.

Fertilizer application at CDA does not result in any significant differences on plant height, however, at Kadawa fertilizer application recorded significantly different means, application of 60kg N ha^{-1} resulted to significantly higher plant height but was at par all other

rates except the control. During the 9 and 12 WAS sampling, application of 120-60-60 kg ha^{-1} resulted to statistically taller plant though it was at par with some of the treatment the control recorded the shortest plant.

Leaf Area Index

Significant effect of biochar and fertilizer on leave area index of maize at CDA are shown in Table 4. Biochar application had no significant effect on the leaf area index (LAI) of maize at any sampling period or location. Fertilizer application significantly influenced LAI at CDA at 9 WAS, where plots treated with full-dose NPK had a significantly higher LAI than the control plots. However, the LAI of these plots was statistically similar to that of other fertilized maize plots. No significant interactions were observed between biochar and fertilizer application across all sampling periods and locations.

Table 3: Response of Biochar and Fertilizer Rates on Plant Height of Striga Infested Maize at CDA and Kadawa during 2024 Rainy Season.

Treatment	Plant Height (cm)					
	BUK/CDA			KADAWA		
Biochar (B)	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
1 tha ⁻¹	27.53	158.52	213.76	26.42a	166.78	212.48a
2 tha ⁻¹	25.82	166.00	204.74	26.05a	172.29	212.69a
SE \pm	0.759	5.912	5.408	0.829	5.031	6.191
Fertilizer (F) (kg ha^{-1})						
NPK	26.13	175.56a	199.67	26.67a	191.93a	225.47a
120:60:60						
NPK	28.67	166.11ab	212.20	25.57a	169.17abc	218.00a
60:30:30						
Nitrogen 120	26.47	168.22ab	221.50	26.82a	179.40ab	222.37a
Nitrogen 60	26.10	153.89ab	206.00	28.47a	151.30bc	213.33ab
Phosphorus	25.67	164.78ab	206.70	25.67a	163.20abc	190.50ab
60						
Potassium 60	27.30	168.06ab	210.93	24.23ab	162.20abc	205.83ab
Control	27.60	143.06b	213.27	20.27b	147.40c	180.33b
SE \pm	1.375	10.239	9.368	1.437	8.714	10.722
Interaction						
BXF	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within same column are not different statistically at $P=0.05$ level of probability using DMRT. NS= Not significant

Cob Weight

The significant effects of biochar and fertilizer on cob weight of Maize at both locations are shown in Table 5. Biochar application had no significant effect on maize cob weight at either location. Fertilizer application significantly affected cob weight at both locations. At CDA Maize plots treated with NPK at 120:60:60 produced significantly heavier cobs per plant than those treated with phosphorus, potassium, and the control plots. However, cob weight in these plots was statistically similar to those treated with NPK at 60:30:30 and nitrogen at 120 and 60 Kg ha^{-1} . at Kadawa Maize plots treated with NPK at 120:60:60 and 60:30:30 produced significantly heavier cobs per plant than those treated with phosphorus and the control plots. However, these were statistically similar to nitrogen-treated plots (120 and 60 Kg ha^{-1}) and the control plots. No significant interactions were observed between biochar and fertilizer application across locations.

Table 4: Response of Biochar and Fertilizer Rates on Leaf Area Index of Striga Infested Maize at CDA and Kadawa during 2024 Raining Season.

Treatment	Leaf Area Index (LAI)					
	BUK/CDA			KADAWA		
Biochar (B)	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
1 tha ⁻¹	1.66	2.31	2.27	1.82	3.53	2.16
2 tha ⁻¹	1.55	2.14	2.17	1.74	3.72	2.43
SE±	0.175	0.134	0.143	0.125	0.307	0.147
Fertilizer (F) (kgha ⁻¹)						
NPK	1.54	2.76a	1.98	1.90	3.61	2.49
120:60:60						
NPK	1.53	2.47ab	2.59	1.73	3.74	2.09
60:30:30						
Nitrogen 120	1.79	2.42ab	2.21	1.99	3.71	2.46
Nitrogen 60	1.48	2.35ab	1.88	1.63	3.60	2.57
Phosphorus	1.69	2.14ab	2.50	1.74	3.91	2.09
60						
Potassium 60	1.72	2.31ab	2.18	1.70	3.20	2.04
Control	1.12	1.69b	2.24	1.31	2.65	2.32
SE±	0.302	0.232	0.366	0.216	0.531	0.255
Interaction						
BXF	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within same column are not different statistically at $P=0.05$ level of probability using DMRT. NS= Not significant

Grain yield (Kgha⁻¹)

Results on the effects of biochar and fertilizer on maize grain yield at CDA and Kadawa are presented in Table 5. Maize plots treated with different quantity of biochar produced statistically similar grain yields, but were significantly higher than the control plots. Fertilizer application resulted in significantly different grain yield at both locations. All maize plots treated with fertilizer, except those treated with potassium alone, exhibited statistically similar grain yields, which were also significantly higher than those of the control and potassium-treated plots. No significant interaction was observed between biochar and fertilizer application across the locations.

The better performance of yield parameters in biochar-treated plots may be due to biochar's ability to increase soil organic matter, enhance soil structure, and improve microbial activity, all of which contribute to maize growth and development. This enhancement occurs through improved assimilate production due to increased LAI and total shoot dry weight, which directly impact maize yield components. Grain yield is the culmination of various yield components and reflects multiple plant growth factors. Biochar application significantly influenced grain yield, as its nutrient content improved soil fertility, water-holding capacity, carbon sequestration, and nutrient use efficiency. Cornelissen *et al.*, (2013) reported an increase in maize yield by 30% – 140% due to biochar application, attributing this to improved grain filling facilitated by favorable soil conditions created by biochar. Namakka *et al.* (2009), also reported that, increasing NPK application up to 120 kg/ha delays tasselling and silking, supporting the findings of this study.

Table 5: Response of Biochar and Fertilizer Rates on Cob Weight and Grain Yield of Striga Infested Maize at BUK/CDA and Kadawa during 2024 Rainy Season.

Treatment	Cob Weight (g) and Grain Yield (kg ha^{-1})			
	BUK/CDA		KADAWA	
Biochar (B)	Cob weight	Grain Yield	Cob weight	Grain Yield
1 tha^{-1}	127.01	4802.30a	148.53	4784.80a
2 tha^{-1}	135.66	5059.20a	146.92	4944.45a
SE \pm	6.355	331.736	6.165	2710.249
Fertilizer (F) (kg ha^{-1})				
NPK 120:60:60	159.11a	5478.90a	164.30a	5681.50a
NPK 60:30:30	127.95ab	5476.00a	159.48a	5663.00a
Nitrogen 120	139.15ab	5416.90a	152.98ab	5407.50a
Nitrogen 60	124.19ab	5390.00a	148.29ab	5355.50a
Phosphorus 60	118.14b	4864.50a	120.07b	5329.50a
Potassium 60	118.04b	2915.40b	141.25ab	1992.50b
Control	114.60b	1592.40b	121.17b	1724.00b
SE \pm	11.008	574.584	10.679	4694.289
Interaction				
BXF	NS	NS	NS	NS

Means followed by same letter(s) within same column are not different statistically at $P=0.05$ level of probability using DMRT. NS= Not significant

Conclusion and Recommendation

The result indicated the application of 60-30-30 $kg\mathit{ha}^{-1}$ NPK plus 2 tha^{-1} biochar gave higher grain yield, cob length and cob weight comparable to the recommended rate of both NPK and biochar and is therefore recommended for farmers in the Sudan Savanna region of Nigeria as they suppress weed infestation and gave higher growth and yield in maize. However, more research should be conducted across different locations with varied ecology to validate the recommendations.

References

- Anonymous (2016). Raw Material Research and Development council on Survey of Agro-raw materials in Nigeria on maize. Maiden Edition Pp. 9-11.
- Babatunde, R. O. Fayode, S. B. and Oluyede, A. A. (2008). Fadama Maize Production in Nigeria case study of Kwara State *Research journal of Agriculture and Biological Sciences* 4(5) 340 - 345
- Cluogh, T. J., Condron L. M., Kamann, C. and Muller, C. (2013). A Review of Biochar Soil Dynamics. *Agronomy* 3 (2) 275 - 293
- Cornilissen, G., Martinsen, V., Shitumbanuma V., Chirwa, P. and Kammann, C. (2013). Biochar effect on Maize Yield and Soil Characteristics in five Conservation Farming Site in Zambia. *Agronomy* 3(2) 256 - 274
- Duncan, D.B. (1955). Multiple range and multiple F-test *Biometrics* 11: 1-42pp.
- Dutt, B. S. (2005). Agricultural geography. New Delhi: Kilyani Publishers
- FAO (2024). Foastat. Retrieved December 12, 2024 from <http://foastat.fao.org/site/339/default>.
- <http://foastat.FAO.org/site/339/default.aspx>.
- Govindra N. J./ (2002), who reported more than a 47% reduction in maize grain yield in control plots compared to those treated with biochar.
- IITA (2009). <http://old.itta.org/cms/details/maize-project-details.aspx?zoneid=63&articleid=273>.

- Namakka, A, Abubakar, I.U., Sadiq, I.A., Sharifai, A.I., Hassan, A.H. and Hussaini, Y. (2009).
Effects of varying sowing date and nitrogen levels on growth of two extra-early maize (*Zea mays* L.) varieties in Sudan Savannah of Nigeria. *Journal of Agricultural Research and Policies*. 1(I): 30-34.
- Ngwu, O.E. (2012). Influence of Biochar on soil properties, Growth and Yield of Maize (*Zea may L.*) *International Journal of Experimental Research*.
- Rego, T. J., Nageswara V., Seeling, B., Pardhasaradi G., and Rao, J. D. K. (2003). Nutrient balances- A guide to improving sorghum and ground nut base dryland cropping system in semi arid tropical India. *Field Crop Research* , 81 (1) 53 - 68
- SAS Institute Inc (2004). Base SAS 9.4 Procedure Guide Statistical Procedures 2nd ed Cary NC institute Inc
- Skjemstad, J. O., Baldock J. A. and Sanderman J. (2004). Soil organic carbon under native vegetation CRC press 2nd ed. Pp.225-238
- Weber J. and Piccolo, A. (1997). Effects of humic substances from oxidized cost on soil chemical properties and maize yield In: The Role of Humic substance in the Ecosystems and in Environmental Protection, Drozd, J., Gonnet, S.S. and Senesi, Mbagwu, S.C.N., (Eds.) pp. 921-925, IHSS, *Polish Society of Humic Substances, Wroclaw, Poland*.