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Research Article

SOIL AND SUGAR QUALITY IMPROVEMENT INFLUENCED BY MULCHING AND WEED MANAGEMENT PRACTICES IN NIGERIA

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Abstract: Yield decline is an issue that has plagued sugarcane production in Nigeria. The objective of the study was to evaluate the effects of sugarcane trash mulch and weed management practices on soil C and N, and sugar quality production. The treatments consisted of factorial combination of two sugarcane genotypes (Bida local and NCS 001), four sugarcane trash mulching levels (0, 3, 6, 9 t ha^{-1}) and four weed management practices: weedy check, 5 monthly hoe weeding (5MHW), pre-emergence (PE) application of diuron at 2 kg a.i./ha + Post-Emergence (POE) of 3-Maize force at 179.2 g/ha + Two hoe weeding (2HW), and PE Diuron + POE 3-Maize force arranged in a split plot design and replicated three times. The results showed that application of 9 t ha^{-1} trash mulch significantly ($P<0.05$) produced the highest organic carbon, N, which in turn enhanced sugar yield. Similarly, the application of 9 t ha^{-1} trash mulch plus PE+POE produced the highest NCS 001 sugar quality. Application of trash mulching at 9 t ha^{-1} plus PE+POE effectively enhanced soil C and N, and sustained the productivity of NCS 001 sugar quality in the study area and related ecologies.

Keywords: genotypes, soil properties, sugar quality, trash mulch, weed management.

Introduction

Sugarcane (*Saccharum officinarum* L.) family Poaceae is widely grown crop in Nigeria. It provides employment to over a million people directly or indirectly besides contributing significantly to the national exchequer [FAOSTAT, 2019]. It is widely grown in several tropical and subtropical countries of the world accounting approximately, 75% of world's sucrose production from sugarcane. Besides the production of raw sugar, of which sugarcane is mainly produced for, sugarcane also represents an important source of renewable energy which has recently gained attention because of ethanol production [PRIYANKA & al. 2019]. In Nigeria, it is grown on an estimated land area of over 500,000 hectares with a yield potential of over three million metric tons of sugarcane [BASSEY & al. 2021].

In the presence of climatic change, land degradation and biodiversity loss, soils have become one of the most vulnerable resources in the world [KANE, 2015]. Soils are a major carbon reservoir containing more carbon than the atmosphere and terrestrial vegetation combined. Soil organic carbon (SOC) is the main component of soil organic matter [KEILUWEIT & al. 2015]. As an indicator for soil health, SOC is important for its contribution to food production, mitigation and adaptation to climatic change. A high soil organic matter content provides nutrients to plants and improves water availability, both of which enhance soil fertility and ultimately improves food productivity [BALDOCCI & al. 2016]. Moreover, SOC

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improves soil structural stability by promoting aggregate formation which, together with porosity, ensures sufficient aeration and water infiltration to support plant growth [FAO & ITPS, 2015].

The gap between domestic production and the demand for sugar can be attributed to many factors. This include rapidly increasing population, increased demand for food, limited scope for extension of cultivation to new areas, diversified low yield potential, food scarcity, heavy importation and not self – sufficient in sugar production. The conventional cropping systems are exhaustive and depleting the soil badly, cultivable lands is decreasing due to urbanization and industrialization, enlarged families, and the current system of monocropping is not able to keep pace with increasing demands of farmers due low yield and subsistence farming is alarming [GEETHA & al. 2015; MOHAMMED & al. 2017].

One potential way to improve sugarcane production among small land holders and meet demand for sugar is by sugarcane trash mulching. Sugarcane genotypes vary in the production of trash which could be attributed to its high in-situ retention of trash as organic manures, replenishing soil quality by increasing soil nutrient status and enhancing chemical properties of the soil [CHOUDHARY & SINGH, 2016]. Weed management practices influences the addition of weed vegetation to the soil which decayed with time. This has also led to high accumulation of organic materials in the release of nutrients from decomposing microbial biomass, which translates to improved physical and chemical soil properties [AZADBAKHT & al. 2017; ABILOYE & al. 2018]. There is an urgent need to integrate these weed management options with trash mulching for improved soil fertility and boost the production of these sugarcane genotypes in order to meet the needs of increasing population. Hence, the objective of the study was to evaluate the effect of varying trash mulch and weed management practices on soil C and N, field sucrose and sugar quality production in the study area.

Material and methods

Field trial was conducted at the upland sugarcane experimental field of the National Cereals Research Institute, Badeggi (latitude 9°45ʹN, longitude 0.6°07ʹE) in the Southern Guinea savanna agro-ecological zone of Nigeria in 2016 and 2017 rainy season. At the commencement of the experiment, a composite sample from ten random points was collected, using a soil auger at 0-15 cm depth for both years. The initial soil properties of the experimental site are shown in Table 1. The total rainfall during the experimental period was 1504.1 mm in 2016 and 1045.4 mm in 2017, respectively. The mean air temperature during the sugarcane plant cropping season was 35 to 38 °C in 2016 and 34 to 36 °C in 2017 plant cropping seasons (Table 2). Prior to cultivation, the vegetative cover of the experimental site was manually cleared, ploughed and harrowed with a tractor. Tender healthy young stalks of six months old sugarcane were used as planting material. The stalks were cut into setts each containing three eye buds. The PE diuron was applied a day after planting at the rate of 2.0 kg a.i/ha while the POE 3-Maize force was applied at five weeks after planting (WAP) at rate of 179.2g a.i/ha. The weeds were identified using the hand book of West African Weeds [AKOBUNDU & al. 2016]. NPK fertilizer was applied at 150 kg N, 60 Kg P and 90 Kg K in equal halves at planting and 8 – 10 WAP. The treatments consists of factorial combination of two sugarcane genotypes, Bida local and NCS 001, four cane trash mulching levels, (0, 3, 6, 9 t ha^{-1}) and four weed management practices: weedy check, 5 monthly hoe weeding (5MHW), Pre-emergence of diuron at 2 kg a.i./ha (PE) + Post-Emergence (POE) 3-Maize force at 179.2 g/ha + Two hoe weeding (2HW), and PE diuron + POE 3-Maize force arranged as a split plot and replicated three times. Herbicides were applied with knapsack (CP3) sprayer at a spray volume of 4 l/ha. Weed management practices and mulching were allocated in the main plot while sugarcane genotypes in the subplot. The gross plot size was 35 m^2 (7 m x 5 m), while the net plot size was 17.5 m^2 (3.5 m x 5 m). Each net plot consists of four rows of 5 m long. All data collected were subjected to analysis of variance (ANOVA). The means were separated using Duncan multiple range test at 5 % level of probability using SAS version 9.0 statistical package.

Results and discussions

The physical and chemical properties of the soil before planting in 2016 and 2017 showed that the soil was sandy loam and slightly acidic (Table 1). The soils were low in nitrogen, phosphorus and other essential nutrients which were inadequate for sugarcane production. In 2016, higher organic carbon was found in plots grown with NCS 001 (Table 2). However, in 2017, organic carbon content was higher in Bida local than NCS 001. The result also shows that NCS 001 had significantly higher total nitrogen in 2017 (Table 3). Application of 9 t ha^{-1} trash mulch was associated with higher soil C and total N contents than that of the lower trash mulch rates (Table 3).With the exception of the weedy check, there was a significant increase in organic carbon and total nitrogen contents in all the other weed management practices in both years (Table 3). The application of Pre-emergence + Post-emergence herbicide produced the highest organic carbon and N. The interaction effects between trash mulch and weed management practices on soil nitrogen was significant (Table 4). Application of 9 t ha^{-1}mulch in combination with PE + POE and PE + POE + 2MHW had the highest Soil N in plant crop in 2016. The significant increase in organic carbon and total N in planted NCS 001 genotype, and only organic carbon content in Bida local genotype suggest their ability in producing and retaining sugarcane crop residues which was influenced by adequate rainfall and temperature. The retention of these residues can be considered as a method of arresting soil organic matter, which has the capacity to hold plant nutrients for sugarcane production [DU PREEZ & al. 2011].

Table 1. Initial soil physical and chemical properties in 2016 and 2017 cropping seasons

Parameter	2016 Site	2017 Site
Sand (g kg^{-1})	722	765
Silt (g kg^{-1})	135	156
Clay (g kg^{-1})	143	79
Textural class	Sandy loam	Sandy loam
pH (H_2O) (g kg^{-1})	5.80	6.40
Organic Carbon (g kg^{-1})	2.37	3.45
Total Nitrogen (g kg^{-1})	0.06	0.33
Available Phosphorus (mg kg^{-1})	20.29	23.15
Ca++ (cmol kg^{-1})	2.48	4.18
Mg++ (cmol kg^{-1})	1.38	3.68
K+ (cmol kg^{-1})	0.16	0.30
Na+ (cmol kg^{-1})	0.09	0.22
Exchangeable acidity (cmol kg^{-1})	1.03	1.07
ECEC (cmol kg^{-1})	5.14	9.45

Analyzed at National Cereals Research Institute Laboratory

Table 2. Temperature and rainfall distribution from 2016 and 2017 cropping season at Badeggi

	Temperature (°C)		**Rainfall (mm)**	
Months	2016	2017	2016	2017
January	36	35	0.0	0.0
February	38	37	0.0	0.0
March	39	39	95.4	4.0
April	40	39	18.7	4.5
May	36	35	220.6	274.9
June	32	33	286.8	146.4
July	31	31	346.1	161.8
August	31	30	203.8	251.7
September	30	30	273.5	202.1
October	33	33	59.2	28.2
November	34	35	0.0	0.0
December	35	34	0.0	0.0
Total	415	375	1504.1	1073.6

Source: Weather station, National Cereals Research Institute Badeggi

Sugarcane genotypes significantly influenced field sucrose (% brix) at 12 MAP (Table 3). Industrial sugarcane recorded the highest sucrose than the local chewing cane. This may be due to the fact that industrial sugarcane has relatively thin and hard stem, thick ring (nodes) and usually contains more sucrose and less water content impacted by favorable rainfall and temperature. This confirms the findings of BUSARI & al. (2009) and SHAH & al. (2009) which states that improved sugarcane (industrial canes) variety usually have thin stems with high sucrose content and less water due to their varied genetic potential of sugarcane genotypes. Furthermore, the highest Brix content was found in sugarcane plants given 6 t ha^{-1}, but similar to that in 9 t ha^{-1} in both years. Field sucrose was highest with the application of monthly hoe weeding which was similar to Pre-emergence + Post-emergence herbicide + 2 hoe weeding and application of Pre-emergence + Post-emergence herbicide only. The interaction effects between trash mulch and weed management practices on brix content was lowest in the non- application of mulch and weedy check treatment while mulch rate at 9 t ha^{-1} mulch in combination with PE + POE produced the highest brix content in plant crop in 2017 (Table 5). This may be attributed to effective weed control which resulted in increasing yield promoting attributes. Our result is in agreement with the previous findings of SMITH & al. (2009) and SINGH & al. (2011) which reported that all the weed control treatments favorably influenced the yield contributing characters such as stalk height, stalk girth and brix.

Sugarcane genotypes and trash mulching had no significant influence on percent polarity at harvest in both years (Table 3). Polarity at harvest was significantly ($P<0.05$) affected by weed management practices (Table 3). Polarity was highest with the application of Pre-emergence + Post-emergence herbicide which was similar to monthly hoe weeding in 2016 and 2017 cropping seasons. The difference in percent polarity of sugarcane genotypes was due to their varied genetic potential which exploit edaphic and aerial factors of crop production. These results are in accordance with those of SHAH &. al. (2009) and BASHIR & al. (2012) who reported significant difference among the sugarcane genotypes for cane polarity. Sugarcane genotypes had significant influence on percent purity at harvest. Industrial sugarcane recorded higher purity than the local chewing cane in both cropping seasons (Table 3). Furthermore, the highest percent purity was found in sugarcane plants given 9 t ha^{-1}, but similar to that in 6 t ha^{-1} in both years. Percent purity was highest with the application of Pre-emergence + Post-emergence herbicide which was similar to monthly hoe weeding in 2016 and 2017 cropping seasons. There was no significant influence of Sugarcane genotypes and weed management practices on percent fibre in both years of study. The variation in sugar quality for sucrose, polarity, purity and fibre could be attributed to heavy tillering, quick canopy formation and weed suppression which were enhanced by incorporation of sugarcane residues resulting in high SOC under the prevailing agro-ecological conditions. These results are in line with those of RASOOL & al. (2011) and GEETHA & al. (2015) who found significant variation in sugar quality for different residues/ sugarcane intercropping. The observed increase in sugar quality content might also be attributed to decrease in weed infestation, increased soil organic matter, improved physical and chemical properties and soil water regimes, which translates into better crop growth. This is in agreement with the work of NG CHEONG & TEELUCK (2015) and DE AQUINO & al. (2017) who reported that variation in sugar quality in sugarcanes could be attributed to varied varietal morphology and weed suppression under the prevailing agro-ecological conditions.

Table 3. Effects of sugarcane genotypes, mulch rates and weed management practices on organic C and N, field sucrose, polarity, purity and fibre at 12 MAP in 2016 and 2017 cropping seasons

Treatment	**Organic C (g kg^{-1})**		**Total N (g kg^{-1})**		**Field sucrose (% brix)**	
	2016	2017	2016	2017	2016	2017
Genotypes (S)						
Bida local	40.47	43.34	0.30	0.38	16.49	16.74
NCS 001	40.49	43.36	0.31	0.39	18.28	18.29
LSD (0.05)	0.005	0.007	0.02	0.005	0.62	0.58
Mulch rate (t ha^{-1})						
0	2.40	3.51	0.09	0.35	16.7	16.6
3	2.47	3.66	0.23	0.47	16.2	17.1
6	2.52	3.82	0.31	0.59	17.8	18.6
9	2.53	3.99	0.50	0.74	18.6	19.3
LSD (0.05)	0.29	0.006	0.009	0.006	0.8	0.7
Weed management (W)						
Weedy check	40.36	43.32	0.28	0.36	16.60	16.30
5 MHW	40.48	43.34	0.30	0.37	18.15	18.38
PE + POE + 2MHW	40.49	43.33	0.32	0.39	17.11	17.38
PE + POE	40.50	43.42	0.33	0.41	17.68	18.0
LSD (0.05)	0.01	0.006	0.005	0.004	1.29	0.82
Interaction						
M x W	NS	NS	*	NS	NS	*
Treatment (cont.)	**Polarity (%)**		**Purity (%)**		**Fibre (%)**	
	2016	2017	2016	2017	2016	2017
Genotypes (S)						
Bida local	19.3	19.3	83.2	82.2	13.0	12.7
NCS 001	19.2	19.4	85.6	85.8	13.4	13.6
LSD (0.05)	0.7	0.6	1.7	1.2	0.9	0.6
Mulch rate (t ha^{-1})						
0	19.1	19.2	83.0	83.5	13.9	13.4
3	19.4	19.2	83.8	83.3	13.2	13.3
6	19.5	19.5	84.9	84.0	12.9	13.4
9	19.2	19.5	85.2	85.2	12.6	12.4
LSD (0.05)	1.0	0.9	2.2	1.7	1.3	0.9

Weed management (W)						
Weedy check	18.4	18.8	83.4	82.4	12.2	12.9
5 MHW	19.6	19.8	85.0	84.8	13.6	13.1
PE + POE + 2MHW	18.7	18.7	83.6	83.7	13.4	13.1
PE + POE	20.2	20.1	86.6	85.2	13.5	13.6
LSD (0.05)	1.0	0.9	2.5	1.7	1.3	0.9
Interaction						
M x W	NS	NS	NS	NS	NS	NS

LSD – least significant difference, MHW – monthly hoe weeding, PE – pre-emergence (Diuron at 2 kg a.i./ha) herbicide, POE – post-emergence (3-Maize force at 179.2 g/ha) herbicide, NS – not significant, * – significant.

Table 4. Interaction between trash mulch and weed management practices on soil total nitrogen ($g\ kg^{-1}$) in 2016 cropping season

Mulch rate ($t\ ha^{-1}$)	**Weed management practices**			
	Weedy check	**5 MHW**	**PE+POE+2MHW**	**PE+POE**
Mulch rate ($t\ ha^{-1}$)	**Plant Crop 2016**			
0	0.08	0.08	0.09	0.12
3	0.19	0.22	0.24	0.25
6	0.26	0.30	0.32	0.36
9	0.42	0.50	0.54	0.56
LSD (0.05)	0.06			

LSD – least significant difference, MHW – monthly hoe weeding, PE – Pre-emergence (Diuron at 2 kg a.i./ha) herbicide, POE – Post-Emergence (3-Maize force at 179.2 g/ha) herbicide

Table 5. Interaction between trash mulch and weed management practices on Brix (%) at 12 MAP in 2017 cropping season

	Weed management practices			
	Weedy check	**5 MHW**	**PE+POE+2MHW**	**PE+POE**
Mulch rate ($t\ ha^{-1}$)	**Plant Crop 2017**			
0	13.52	17.87	16.00	18.05
3	15.42	17.63	16.93	16.43
6	17.88	18.67	17.60	18.40
9	18.38	19.33	18.98	19.12
LSD (0.05)	6.68			

LSD – least significant difference, MHW – monthly hoe weeding, PE – pre-emergence (Diuron at 2 kg a.i./ha) herbicide, POE – post-Emergence (3-Maize force at 179.2 g/ha) herbicide

Conclusion

This study has shown that the application of 9 t ha trash mulch with 5 MHW or PE diuron plus POE 3-maize force effectively increased some soil C and N, field sucrose and cane sugar quality, especially NCS 001 in this agroecology of Nigeria.

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