The Journal of Animal & Plant Sciences, 24(1): 2014, Page: 329-335
ISSN: 1018-7081

EVALUATION OF ORGANIC MULCH ON THE GROWTH AND YIELD OF SUGARCANE (*Saccharum officinarum* L.) IN A SOUTHERN GUINEA SAVANNAH OF NIGERIA

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ABSTRACT

Sustainability in crop production could be achieved using agricultural wastes which litter the environment to ameliorate crop soils. The effect of organic mulches on the growth and yield of two sugar cane varieties (NCS 008 and Bida local) was therefore evaluated during 2010 (plant crop) and 2011 (ratoon crop) at Badeggi (9^0 03'N, 06^0 09'E; altitude 89 m a.s.l.) Nigeria. Mulch materials (rice husk and groundnut shell) were each applied at the rates of 0, 20 and 40 tonnes ha^{-1} in a factorial experiment laid out in a randomised complete block design (RCBD), with three replications. The variety NCS 008 produced significantly ($p<0.05$) higher number of tillers, stalk length, yield and chewable stalks in both the regular and ratoon crops relative to the local. The establishment count of NCS 008 was higher compared to Bida local (73% vs. 38%) in the ratoon and vice versa in the plant crop. Mulching with groundnut shell produced significantly ($p<0.05$) higher establishment count and stalk lengths compared to rice husk mulch for the ratoon crops, but did not differ appreciably in the main (plant) crop. Irrespective of the cropping system, stalk girth, tiller count, chewable stalks and yield were significantly ($p < 0.05$) higher with groundnut shell compared with rice husk mulch. Aside from establishment count, which had an inverse relationship with mulching rate in the plant crop, all the other traits assessed had a direct relationship with mulching rate in the two systems. The interaction effect of variety x organic mulch x organic mulch rate were also significant ($p<0.05$) for both the plant and ratoon crops on most of the parameter considered.

Keywords: Agricultural waste, chewing and industrial cane, cropping system, regular and ratoon crops

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of the most significant commercial and cash crops grown by farmers in countries of the tropics (Alvaris, 2008) and improves the socio-economic conditions in various aspects. Most recently, considerable amount of research have been directed at increasing biomass production of sugarcane. The crop is used for the production of sugar, molasses for livestock feeds, alcohol, bagasses used for cooking fuel (Junejo *et al.*, 2010), and trash used for mulching and as organic fertilizer (Gana, 2008). In Brazil, sugarcane is readily available as forage for dairy cattle. Sugarcane is used as strategic forage particularly in the dry season to prevent overgrazing of the pasture and for wine making (Hussain *et al*., 2007). Chewing sugarcane can locally be processed into *mazarkwaila* and *alewa* for drinking *akamu* and *gari* (Busari *et al*., 1995).

The application of nutrients either as chemical fertilizers or organic manure was found to reduce *striga* infestation and improve crop yield (Gana *et al*., 2007). In sandy soils, especially in upland ecologies, loss of mineral nutrients, water and herbicides through leaching is very high thereby making the soil unproductive (Busari *et al.*, 2000). Poor growth performance of chewing sugarcane was observed by Gana and Busari (2001) when inorganic fertilizer at the recommended rate of 120 N – 60 P_2O_5 – 90 K_2O kg ha^{-1} was applied to chewing sugarcane at Badeggi, Nigeria. Ishaq and Olaoye (2007) observed poor canopy formation of sugarcane in a low nutrient soil which resulted in poor weed control. In developing countries, continuous cropping on an area over a long period, result in the depletion of soil nutrients to the detriment of the agricultural crops. The use of fertilizers therefore becomes imminent. Inorganic fertilizers were therefore employed to supply lost nutrients as nutrient uptake varies with crops. Inorganic fertilizers are costly and mostly not available. High cost and scarcity of inorganic fertilizers in developing countries led to renewed interest in the use of unorthodox organic materials as nutrient source for the cultivation of nutrient demanding crops (Ahmed *et al*., 2007)

Nutrient budget for sub Saharan Africa shows a net annual depletion of N, P and K as a result of long term cropping, with little or no external nutrient inputs (Agboola, 1995). The application of organic materials is needed not only to replenish lost nutrients but also to improve the physical, chemical and biological properties of soil ecologies, which will enhance the performance of soil and sufficient utilization of the applied inputs.

According to Gana and Busari (2001), manure increases organic matter content, water holding capacity and plant nutrients in the soil. It also increases the efficiency of mineral fertilizers by improving physical properties of the soil. Farmers in the Sudan Savanna zone use a lot of organic fertilizer for their crop production because of high cost of inorganic fertilizer (Gana, 2008). Even prior to the introduction of mineral fertilizers in Nigeria some 80 years ago, manure, compost and FYM were particularly the early source of nutrients to crop (Gana and Busari, 2001).

In 2002, about 2,699,000 tons of groundnuts were produced on about 2,783,000 hectares of land. Meanwhile, groundnut shell has been categorized under organic waste (Alabadan *et al*, 2005). Groundnut shell has been used as organic material in replacement of cow dung with a measure of good success (Alabadan *et al.*, 2005). According to Busari *et al*. (1995), the effect varies according to the inherent physical and chemical properties of the soil particularly on the nature and content of the clay and humus colloid. Organic fertilizer helps in improving soil structure, soil aeration and therefore, improving the activities of soil micro-organisms (Agboola, 1995).

Mulching with rice husk at 20 t ha^{-1} was reported by Ogwulumba *et al*, (2010) as most effective in the control of weeds and nematode infection. Moisture reserve was found to be highest when mulched at 8 t ha^{-1} using rice husk, followed by 6 t ha^{-1} with the unmulched control recording the highest weed infestation, which eventually resulted to the poorest maize yield (Uwah and Iwo, 2011). Rice husk is recognized as an important source of energy, particularly in developing countries where its economy is largely based on agriculture and forestry. Agricultural waste is one form of biomass which is readily available but is largely not utilized in energy recovery schemes. Rice husk is an agricultural waste produced as a by-product of the rice milling industry. Banana requires a good supply of organic manure for its proper development. Organic manure of plant and animal origin is a valuable source of crop nutrients, which can improve soil biophysical conditions required for sustainable food production (Baiyeri and Tenkouano, 2007).

Mulching suppresses weed germination and retard growth and development of many weeds (Uwah and Iwo, 2011). Therefore, the objective of this study was to determine the effect of different organic mulch emanating from different agricultural wastes and their rates on the growth and yield of sugarcane under regular and ratoon cultures.

MATERIALS AND METHODS

The studies were conducted at the upland sugarcane experimental field of the National Cereal Research Institute Farm, Badeggi (9^0 $03^{'}$N, 6^0 $09^{'}$E; altitude 89 m a.s.l.) in the Southern Guinea Savanna ecological zone of Nigeria during 2010 regular culture and 2011 ratoon culture. The soil at the site of the trial has been classified as ultisol and sandy loam in texture with a bulk density of 1.459 m^{-1} (Ayotade and Fagade, 1993). The site has an average annual rainfall of 1124 mm and mean temperature of 23^0 – 33^0C. Two varieties of sugarcane used for the experiments included chewing sugarcane (Bida Local) and industrial sugarcane i.e. National Cereals Sugar 008 (NCS 008). Chewing sugarcane (Bida Local) is usually more robust, with less sucrose and softer than the industrial type. It is normally chewed by the people and could be locally processed into "*mazarkwaila*" and "*alewa*" used alone or mixed in foods. Chewing sugarcane is purple in colour, and can attain a stalk length of 2.0 – 3.0 meters. It takes about 10 months to mature. The production of this crop is in the hands of the local farmers who cultivate with less farm holdings of 0.2 – 2.0 ha. Industrial cane, NCS-008 was developed at National Cereals Research Institute (NCRI), Badeggi, Nigeria and released in 2006. It has erect stools at maturity and exhibit heavy stool habit. It is early maturing (9-11 months) and high yielding (90 t ha^{-1}). It is moderately resistant to smut and strives well in different soil types. The variety is also tolerant to stem borer and termite with heavy tillering and good ratoon ability. The organic materials used during the experiment were rice husk (RH) and groundnut shell (GS) at the rates of 0, 20 and 40 tonnes ha^{-1}. The treatment design constituted factorial combinations of the two cane varieties, the two mulching materials and the three mulching rates arranged in a randomized complete block design (RCBD) with three replications.

The plot size was 6 m^2 (3 m x 2m); each containing 4 rows of sugarcane. A 1.0 m pathway was maintained between plots and 1.5 m between blocks; with an inter-row spacing of 1.0 m. The total number of plots per block was 12; giving a total of 36 plots for the 3 blocks. The total land area was 408 m^2. Three setts of sugarcane were planted per row during the experiment. Ratoon for this experiment was observed during the next cropping season of 2011. Parameters assessed included establishment count, number of tillers per plant, stalk length, stalk girth (cm), number of chewable stalk and yield per hectare. All data collected were subjected to analysis of variance (ANOVA) to test treatment effects for significance using GENSTAT Edition 3 statistical package. The means were compared using F-LSD as described by Obi (2002).

RESULTS AND DISCUSSION

The establishment count significantly ($p<0.05$) differed in both the plant and the ratoon crops for the two varieties (Table 4). This is such that in the plant crop, Bida local had higher establishment count (45%) compared to NCS 008 (37.72%). Conversely, the establishment count of NCS 008 in the ratoon crop (74%) was significantly ($p<0.05$) higher relative to that of Bida local. Generally, the organic mulches used did not differ significantly amongst each other or their various rates used in the regular culture. However, in the ratoon crops, mulching with groundnut shell produced higher establishment count (60%) compared to rice husk with 52% establishment count. Also, increasing organic matter rate increased the establishment count in the ratoon crops such that highest per cent count of 62% was attained at 40 t ha^{-1}. The effects of variety x organic mulch, variety x organic rate or organic mulch x organic rate did not attain statistical significance in plant crop but attained significance during ratoon crop (Table 5). However, mulching NCS 008 with groundnut shell at 40 t ha^{-1} gave the highest establishment count of 86 % at ratoon (Table 5). In all the sampling periods, the stalk lengths of NCS 008 variety were significantly ($p<0.05$) higher compared to those of Bida local in both cropping systems. The stalk lengths of the plant crops mulched with groundnut shells were significantly ($p<0.05$) higher compared to those of rice husk. The interaction between varieties x organic mulch was significant for plant and ratoon crops. The interaction result (Table 4) showed that the highest stalk length was obtained with the application of 40 t ha^{-1} for both the plant and ratoon crops which attained the maximum heights of 293.00 cm and 139.40 cm for the plant and ratoon crops respectively compared to other treatment combinations. This may be attributed to relatively higher moisture reserve and better weed suppression at 40 t ha^{-1} compared to other lower levels. Bida local established faster than NCS 008 at plant crop was expected because chewing canes are softer than industrial canes (Busari *et al*., 2000). But in ratoon crop, industrial cane established faster because it is capable of withstanding drought more than the chewing cane (Ishaq and Olaoye, 2007). The significant mulching effect in the ratoon crop is in agreement with Gana (2008), who stated that the higher the applied quantity of organic mulch, the more the sustainability of the crop on the field. Thus, it does appear that the effect of the mulch was more pronounced during the ratoon, following the full decomposition and release of nutrients in the mulch materials. In relative terms, sugarcane with higher mulching rate therefore produced appreciably more establishment count, number of tillers, stalk length, stalk girth and yield because moisture is more reserved and evaporation from the soil is reduced. According to Singh *et al.* (1999) mulching is beneficial to cane cultivation in dry months and during earthening up. It limits the water losses and soil erosion over the surface of the field (Akhtar *et al.,* 2001). In this manner it plays a positive role in water conservation and the suppression of evaporation which has supplementary effect. It also prevents the rise of water containing salt, which is important in countries with high salt content water resources (Enan, 2004). Hence, it suppressed weed germination and retarded growth and development of many weeds (Uwah and Iwo, 2011). They also indicated that mulching also reduced soil erosion and conserved soil moisture. Most of the soils where sugarcane is grown in Nigeria are low in nutrient. This is coupled with long-term monocropping as a consequence of its perennial ability to ratoon severally after harvesting and land scarcity justifies continued use of inorganic fertilizer on the same field. The results obtained from this study revealed that waste material can be used to improve the soil to attain maximum yield. The use of waste materials from agricultural product can be used to improve the soil; this waste also serves as a mulching material for the growth and development of sugarcane on the field. However, growers should add organic waste to ratoon crops to achieve maximum sugarcane yields. Improving soil organic matter and soil fertility are important factors in the sustainability of sugarcane (*Saccharum spp.*) production (Gana, 2008).

Generally, the stalk girths of Bida local were significantly ($p<0.05$) higher than those of NCS 008 in all the sampling periods for both the plant and ratoon crops (Table 4). Crops mulched with groundnut shell produced significantly ($p<0.05$) larger stem girths compared to those mulched with rice husks in the sampling periods and cropping systems. Also, for both cropping systems, stalk girth significantly ($p< 0.05$) increased with increase in organic mulch rate in the sampling period, such that mulching at 40 t ha^{-1} produced the highest stalk girth. NCS 008 variety produced significantly ($p< 0.05$) the highest tiller count per stool compared to Bida local, irrespective of the cropping system. In all the cropping systems, mulching with groundnut shell produced significantly ($p< 0.05$) the highest number of tillers per stool than situations where rice husks were used. In the two cropping systems, increasing organic mulch rate significantly ($p< 0.05$) increased tiller count (Table 4).

The sugarcane variety NCS 008 produced significantly ($p< 0.05$) more chewable stalks compared with Bida local for both cropping systems (Table 4). Also in the two system, mulching with groundnut shell gave significantly ($p< 0.05$) more chewable stalks than where rice husks were used. Increasing mulch rate significantly ($p< 0.05$) increased the number of chewing stalks in both the plant and the ratoon crops. The variety NCS 008 produced yields of 42.25 and 50.31 t ha^{-1} for both the regular and ratoon crops respectively, which were significantly ($p<0.05$) higher than 31.82 t ha^{-1} and 23.65 t ha^{-1} respectively obtained from Bida local. Mulching with groundnut shell gave a better yield than rice husk. Mulching at 40 t ha^{-1} gave the best yield of about 55 t ha^{-1} for the plant crops and 51 t ha^{-1} for the ratoon crops compared to other lower rates. The increased in number

Table 1. Meteorological data showing mean monthly rainfall (mm), temperature (^{0}C) and relative humidy (%) of the study area (NCRI) Badeggi.

	2010				2011			
	Temperature (^{0}C)		Rainfall (mm)	Relative Humidity (%)	Temperature (^{0}C)		Rainfall (mm)	Relative Humidity (%)
Month	Max	Min			Max	Min		
January	35	17	0.00	62	35	14	0.0	50
February	38	22	0.00	66	37	24	9.8	62
March	39	26	0.00	47	38	26	0.0	65
April	38	27	36.7	64	38	26	53.3	63
May	25	25	173.0	78	34	24	101.6	78
June	33	26	106.1	81	33	23	259.4	83
July	30	25	338.3	86	30	22	263.2	85
August	31	23	264.9	87	31	22	289.7	84
September	32	23	130.2	86	32	22	101.2	84
October	32	23	224.2	85	33	19	0.0	67
November	35	19	14.1	76	35	16	0.0	61
December	35	19	0.00	58	35	16	0.0	54

Table 2. Physio-chemical properties of soil taken from experimental site

Soil properties 0-25 cm depth	2010	2011
Physical properties		
Sand (%)	67.52	69.51
Silt (%)	7.92	6.34
Clay (%)	25.84	23.16
Textural class	Sandy clay loam	Sandy clay loam
Chemical properties		
pH in water	5.70	5.13
Organic carbon (%)	0.45	0.26
Organic matter (%)	0.78	0.52
Total nitrogen (%)	0.04	0.02
Available phosphorus (ppm)	0.13	0.16
Exchangeable cation (C mol/kg^{-1})		
K	0.10	0.11
Mg	21.05	23.17
Ca	8.08	9.12
Na	0.16	0.23
CEC (C mol/kg^{-1})	30.05	34.18

of chewing cane is not suprising because Uwah and Iwo (2011) discovered that mulched plots produced more numbers plant and yield per hectare when compared to plots from those were not mulched control. In addition, mulching significantly reduced the direct heating of sun on plant and soil, therefore, improving moisture regime and nutrient uptake. More numbers of tillers were significantly produced in NCS 008 than Bida local, which showed significant increase on the number of chewable stalk. This may be as a result of industrial cane being thinner that chewing cane (Gana, 2008). More cane yield was produced in NCS 008 than Bida local, probably because of its better response to organic mulch, which improved soil structure and aeration and thereby reduced excessive leaching and consequently increased yield (Agboola, 1995). According to Olaniyi and Ojetayo (2010) there is need to adopt the use of organic farming to increase farmers' yield

The interaction between varieties x organic mulch was significant for both plant and ratoon crops (Table 5). The interaction result showed that the highest stalk length was obtained with the application of 40 t ha^{-1} in the two cropping systems, which attained the maximum heights of 293.00 cm and 139.40 cm, respectively compared to other treatment combinations. Combinations of variety x organic mulch, variety x organic matter rate, organic mulch x organic mulch rate or variety x organic mulch x organic rate significantly ($p<0.05$) affected stalk girths and cropping systems. This is such that in the two cropping systems, interactions of Bida local and groundnut shell at 40 t ha^{-1} or Bida local and rice husks at 40 t ha^{-1} produced the biggest stalk girth. Combinations of variety x organic mulch or variety x organic rate also significantly ($p< 0.05$) affected tiller counts. The highest tiller numbers of about 33 and 20 were produced by the plant and ratoon crops respectively, by NCS 008 mulched with groundnut shell. Similarly, mulching of both the plant and the ratoon crops of NCS 008 at 40 t ha^{-1} gave the highest tiller counts of 35 and 23 respectively. There was a significant variety x organic mulch interaction effect on chewable stalks. For the chewable stalks also, there was a significant ($p< 0.05$) variety x organic rate for the both cropping systems. Organic material x rate interaction was only significant ($p< 0.05$) for the plant crops, but not for the ratoon crops. The interaction of variety x organic mulch x organic rate was significant ($p< 0.05$) for both crops such that NCS 008 mulched with groundnut shell at 40 t ha^{-1} produced the highest number of chewable stalks compared with other combinations at 12 MAP. Variety x organic mulch x rate effect was significant ($p < 0.05$) on the plant crops such that the best yield was produced by mulching NCS 008 with groundnut shell at 40 t ha^{-1}, which gave 72 t ha^{-1}. This could be attributed to the response of an improved variety (industrial cane) to higher moisture conservation and weed suppression potentials of mulching at 40 t ha^{-1} relative to other rates and variety. The obtained yield is higher than the average yield per ha in Africa, which is 53.2 t ha^{-1} (FAO, 1994). In Africa, South Africa and Egypt are the leading sugar producing countries with about 15 million metric tons and about 12 million metric tons respectively per year. Busari (2004) observed decline in sugarcane yield production in Nigeria to 30 – 40 t ha^{-1}. In this result, a yield of 72.57 t ha^{-1} was obtained in the ratoon crop of 2011 with the use of 40 t ha^{-1} groundnut shell as organic mulch material. Ratoon yield obtained from this study was higher than the yield obtained from plant crop. This is contrary to Malik (2010), who reported that ratoon generally yield lesser cane weight. Akhtar *et al*. (2001) observed that ratoon is considered a "free crop" and given no proper care ultimately results in low cane yield. However, the obtained result is in agreement with Singh (2011) who reported that ratoon crop helps in obtaining higher yield recovery due to its early maturity ability than the plant crop in the early part of the crushing season.

Table 3. Chemical composition of rice husk and groundnut shell used

	Rice Husk	Groundnut Shell
pH	6.40	4.50
Organic carbon (%)	2.23	2.08
Organic matter (%)	3.84	3.50
Nitrogen (%)	12.44	16.25
K (C mol/kg^{-1})	1.04	0.03
Mg(C mol/kg^{-1})	1.41	2.65
Ca (C mol/kg^{-1})	3.63	0.72
Na (C mol/kg^{-1})	1.24	1.49
Available phosphorus (ppm)	2.6	1.94
CEC (C mol/kg^{-1})	7.60	5.29
EA (C mol/kg^{-1})	0.28	0.40

Table 4. The effects of sugarcane varieties, organic materials and rates, and their interactions on the establishment count, stalk length and girth, chewable stalk and tiller count and yield (Kg ha^{-1}) for plant and ratoon crops.

Treatment	Estab. count		Stalk length (cm)		Stalk girth (cm)		Chewable stalk count		Tiller count		Yield (Kg ha^{-1})	
	PC	RC	PC	RC	PC	RC	PC	RC	PC	RC	PC	RC
Varieties												
Bida Local	45.10	37.72	132.72	73.78	5.26	4.02	37.61	27.89	13.39	8.06	31.82	23.65
NCS 008	36.40	73.90	240.28	87.82	3.27	2.47	57.78	64.22	24.56	19.22	42.25	50.31
F-LSD $_{(0.05)}$	5.15	6.30	1.79	0.93	0.12	0.08	1.45	0.98	1.14	0.67	1.10	1.42
Organic Material												
GS	39.50	59.79	196.83	99.40	4.49	3.38	51.72	61.44	21.22	15.11	41.03	39.31
RH	42.00	51.83	176.17	87.82	4.03	3.12	43.67	30.67	16.72	12.17	33.03	34.46
F-LSD $_{(0.05)}$	NS	6.30	1.79	0.93	0.12	0.08	1.45	0.98	1.14	0.67	1.10	1.42
O M Rate (t/ha)												
0	43.70	48.42	150.33	83.02	3.34	2.48	37.41	30.33	15.25	9.42	15.36	22.50
20	40.00	57.36	191.50	95.57	4.25	3.27	43.67	35.95	18.83	13.92	41.22	36.89
40	38.40	61.66	217.67	101.92	5.20	3.99	57.17	41.92	22.83	17.58	54.52	51.36
F-LSD $_{(0.05)}$	NS	3.11	2.19	1.14	0.14	0.09	1.78	1.21	1.40	0.82	1.34	1.74
Interaction												
V x OM	NS	NS	2.53	1.31	0.16	0.11	2.05	NS	NS	NS	1.55	2.01
V x OR	NS	NS	3.10	1.61	0.20	0.13	2.51	NS	NS	NS	1.90	2.46
OM x OR	NS	NS	3.10	1.61	0.20	0.13	2.51	NS	NS	NS	1.90	2.46
V x OM x OR	NS	1.80	4.39	2.28	0.28	0.19	3.56	2.41	NS	NS	2.68	NS

PC- plant crop, RC- ratoon crop, GS- groundnut shell, RH- rice husk, V- variety, OM- organic material, OR- organic rate, F-LSD- Fisher's least significant different at 5% level of probability and NS-non significant.

Table 5. Interaction effects of sugarcane varieties, planting part, K-fertilization and their interactions on the establishment count, stalk length and girth, chewable stalk and tiller count, % Brix and yield (Kg ha^{-1}) for plant and ratoon crops

Varieties	PP	KF(kg ha^{-1})	Estab. count	Stalk length (cm)		Stalk girth (cm)		Chewable stalk count		Yield (Kg ha^{-1})
			RC	PC	RC	PC	RC	PC	RC	PC
Bida Local	GS	0	30.32	106.33	66.87	4.43	3.60	25.67	28.33	11.70
		20	41.14	154.33	79.90	5.20	4.30	47.00	33.33	39.97
		40	46.37	171.67	83.23	6.40	4.90	48.67	37.67	53.87
	RH	0	29.68	103.00	62.60	4.10	2.80	29.00	15.33	11.53
		20	36.27	125.67	73.50	5.13	2.93	34.00	23.67	33.00
		40	42.56	135.33	76.57	6.27	4.60	41.33	29.00	40.83
NCS 008	GS	0	73.81	194.33	102.43	2.63	1.87	51.67	62.67	19.17
		20	81.21	261.33	124.57	3.53	2.53	61.00	68.00	49.57
		40	85.89	293.00	139.40	4.77	3.07	76.33	78.67	71.93
	RH	0	59.86	197.67	100.20	2.20	1.67	45.33	35.00	19.03
		20	70.83	224.67	104.33	3.13	2.30	50.00	38.67	42.37
		40	71.82	270.67	108.50	3.37	3.40	62.33	42.33	51.43
F-LSD$_{(0.05)}$			1.80	1.50	2.28	0.28	0.19	3.56	2.41	2.68

PC- plant crop, RC- ratoon crop, TP – top part, MP – middle part, BP – base part, PP – planting part, V – variety, KF – potassium fertilization, F-LSD- Least significantly different at 5% level of probability and NS – not significant.

Conclusion: Organic mulch rate had significant effect on the production of sugarcane. The best was observed from the plot mulched with 40 t ha^{-1} of groundnut shell. NCS 008 performed better than Bida local and groundnut shell did better than rice husk for each parameter considered. Application of organic mulch therefore should be encouraged and recommended for effective production of sugarcane for optimum yield.

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