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RESEARCH ARTICLE

Weed and disease management strategies for sustainable sugarcane production

Akammaa Clement Wada*

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Abstract

Weed and disease management strategies for sustainable sugarcane production were investigated by using two sugarcane genotypes, Bida local and commercial NCS 001, four rates of sugarcane trash mulch rates of 0, 3, 6, 9 t ha-1 and four weed management practices namely weedy check, monthly hoe weeding for five months (5 MHW), application of PE diuron + POE 3 – maize force, and application of PE diuron plus POE 3 – maize force + 2 MHW at Badeggi (Lat. 9° 45´ N, Long. 06° 07´ E). The treatments were arranged in a split-plot design and replicated three times in 2016 and 2017 cropping seasons. Results showed that application of 6 t ha-1 mulch produced comparable but lower weed dry matter and whip smut incidence to 9 t ha-1 mulch. Application of PE diuron plus POE 3 – maize force and 5 MHW, resulted in a comparable weed dry matter and whip smut incidence to PE diuron plus POE 3 – maize force plus 2 MHW. Similarly, PE diuron plus POE 3 – maize force, 5 MHW and PE diuron plus POE 3 – maize force plus 2 MHW produced comparable stalks and brix content, number of stools and millable stalks. Also, 5 MHW generated taller sugarcane plants. The application of PE diuron plus POE 3 – maize force proved equally effective as 5 MHW in contributing the highest cane yield. Lower weed dry matter was recorded in Bida local, and taller stalks, maximum cane girth, higher brix content, number of stools, millable stalks, lower whip smut incidence and cane yield were recorded in NCS 001. In all, application of 9 t ha^{-1} trash mulch with 5 MHW or PE diuron plus POE 3 – maize force plus 2 MHW or PE diuron plus POE 3 – maize force strategies effectively managed weeds and smut incidence in the present study. The strategies also increased stalk height, cane girth, brix content, number of stools, millable stalks and cane yield of genotype NCS 001.

Keywords: Bida local chewing cane; Genotype NCS 001; Whip smut incidence; Trash mulch; Cane yield.

National Cereals Research Institute, Badeggi PMB 8, Bida, Niger State, Nigeria.

***Correspondence:** drwada2013@gmail.com

Introduction

Sugarcane (Saccharum officinarum) family Gramineae (Poaceae) is a 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 for approximately 75 % of the world's sucrose production from sugarcane (Wada et al., 2017). 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 et 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 (Bassey et al., 2021).

The gap between the average and potential yield of sugarcane in Nigeria is mostly due to a number of factors. These include poor crop management and cultural practices like the use of low-yielding varieties for the different agroecologies, water scarcity and lack of irrigation system in drought-prone environments, improper agronomic practices like the inappropriate use of plant density, inappropriate fertilizer use and poor disease management methods and timeliness, and unplanned harvesting schedules. Others are lack of access to credits and rises in production cost, unpredictable weather patterns, and inadequate research and extension support (Achieng et al. 2013; Nadir et al., 2015, Tena et al. 2016). In addition, biotic factors, especially weeds and disease effects limit optimum sugarcane yield (Takim and Suleiman 2017; Wada and Anaso 2016). Wada et al. (1998, 1999) reported whip smut as the most important disease of sugarcane in Nigeria.

The estimated potential yield losses of sugarcane due to weeds vary between 24 and 93%, especially among farmers that are not familiar with improved weed management options (Takim and Suleiman 2017).

Reduction in yield components and cane yield losses due to whip smut disease has been reported by Wada and Anaso (2016). Besides, in this agroecology in Nigeria, the common sugarcane types under production are chewing cane for human consumption and commercial cane as raw materials for the sugar and sugar-related industries.One potential way to reduce the negative effects of weeds and diseases in the production of these sugarcane genotypes is to use large amounts of trash usually produced by sugarcane as mulch. Sugarcane trash used as mulch can contribute significantly to the yield of sugarcane by its ability to smother weed germination and emergence, conserve soil moisture, add nutrients to the soil on decomposition and modify the soil condition (Carvalho et al. 2017). For example, in Brazil, mulching the soil with above-ground parts of Crotolaria spectabilis, C. ochroleuca, C. breviflora and Cajanus cajan efficiently managed weeds in relation to the preemergence application of herbicides at 60 days after planting of sugarcane (De Cerqueira et al. 2018). In Nigeria, the application of organic mulch has been recommended for optimum sugarcane production (Ahmed et al. 2014). Organic mulches help in the nutrition of many beneficial organisms that compete for the incoming pathogenic spores or sometimes release chemicals for the inhibition of pathogens; in this way, they reduce the chances of disease spread (Chalker-Scott 2007).

There are many ways of disease reduction in plants through mulches. Sampathkumar et al. (2006) reported that the needles that suffered from blight disease worked as mulch on the surface for the better growth of tree species. Mulches have a direct or an indirect mechanism to lessen the disease. This mechanism was also elaborated by Downer et al. (2002) who discovered the root rot disease through short- and long-term mulching effects. The indirect effects of mulches are helpful for the prevention of plant diseases such as improvement in the nutrition of plants, better drainage, moderation of soil temperature, improved soil aggregation, and conservation of soil moisture. Consequently, mulch materials provide healthy conditions for crop plants which optimize the vigorous growth and development of plants that may remain safe from pathogenic organisms (Turchetti et al. 2003).Other ways to improve the yield of sugarcane, irrespective of the genotypes, is through weed management practices. For example, in India, pre-emergence application of metribuzin at 1.4 kg a.i ha-1 followed by 2,4—D at 1.6 kg a.i ha at 45 days after ratoon initiation significantly reduced weed growth and increased the growth and yield of sugarcane compared to weedy check (Kumar et al. 2014). Also, in Nigeria, pre-emergence application of terbuthylazine at 2 kg a.i ha-1 plus three supplementary hoe weeding (as for the small-scale growers) or post-emergence application of 2, 4— D at 3 kg a.i ha^{-1} (for the commercial estates) resulted in reduced weed growth and increased yield of sugarcane (Takim and Suleiman 2017). Azadbakht et al. (2017); Abiloye et al. (2018) and Bassey et al. (2021) reported that, PE diuron and POE 3-maize force application significantly reduced weed biomass by a slow rate of decomposition, which is related to its high concentrations of organic carbon, soil moisture content and reduced rate of evapotranspiration resulting from changes in the C/N ratio and allelopathy which translates to reduce the chances of whip smut disease incidence.

Research information on weed and disease management for sugarcane when sown under different rates of sugarcane trash mulch, weed management practices and whip smut incidence is scarce in Nigeria. Hence, the objectives of this study were to evaluate the effects of varying sugarcane trash mulch and the application of weed management practices on weed and disease management for sustainable sugarcane production.

Materials and Methods

A field trial was conducted at the upland sugarcane experimental field of the National Cereals Research Institute, Badeggi (Lat. 9° 45´ N, Long. 06° 07´ E) in the southern Guinea Savanna agroecological zone of Nigeria in 2016 and 2017. Before cultivation, the vegetative cover of the experimental site was manually cleared, ploughed and harrowed with a tractor in the first week of February 2016 and 2017.

The land was fully irrigated before planting by pumping water from a stream using a 3.5 HP water pump with a 12.5 cm diameter hose. Thereafter, the land was marked out into plots with bunds at the edges for water retention. The gross plot size was 5 m x 4 m (20 m2) consisting of 4 sugarcane rows, and the net plot size was 5 m x 2 m (10 m2) consisting of 2 sugarcane rows. Each row was spaced 1 m apart.

Tender healthy young stalks of seven months old of the two sugarcane genotypes were used as planting material. The stalks were cut into setts each containing three eye buds, planted continuously end-to-end without intra-row spacing in shallow sunken furrows which were later earthened up at 3MAP. The application of pre-emergence (PE) diuron was done immediately after planting at 2.0 kg a.i ha^{-1}.

The application of post-emergence (POE) 3 – maize force [metolachlor 375 g L-1 plus terbuthylazine 125 g L^{-1} plus mesotrione 37.5 g L-1] at 179.2 g ha-1 was applied at 5 weeks after planting (WAP). The NPK fertilizer was applied at 150 kg N, 60 Kg P2O5 and 90 Kg K2O in equal halves at planting and 10 WAP. Irrigation water was applied at 41.3 L per plot once per week from February to April. Rainfall was supplemented with irrigation in May which marked the establishment of the rainy season.

The treatments consisted of a factorial combination of two sugarcane genotypes of chewing cane or Bida local and commercial cane (NCS 001), and four weed management practices viz: weedy check, monthly hoe weeding for five months (5 MHW), application of PE diuron + POE 3 – maize force, and application of PE diuron plus POE 3 – maize force + 2 MHW] arranged in a split-plot design and replicated three times. Weed management practices were allocated to the main plot, while the two sugarcane genotypes were the subplot.

Herbicides were applied with knapsack (CP3) sprayer at a spray volume of 4 L ha^{-1} at 206 KPa. Weed species samples in each plot were collected from a 1 x 1 m2 quadrat at 3, 6 and 9 months after planting (MAP). Weed species seedlings in each quadrat were clipped at the soil level and identified according to Akobundu et al. (2016). The weed species were counted to determine the weed density on a plot basis and expressed in number per m2. The weed samples were oven-dried at 80^{o} C to a constant weight and weighed to determine the dry matter in g per m2. Plant height was taken at 12 MAP was taken from the soil level to the top visible dewlap (TVD) using a graduated ruler. Stalk girth measured in centimeters was taken at 10 MAP using a pair of Vernier callipers. Percent brix at harvest at 12 MAP was taken using Hand refractometer to determine the level of field sucrose.

Sugarcane stools per plot were taken by counting the number of stools at 12 MAP with the aid of a tally counter. Millable stalks per stool were taken by counting the number of stalks at 12 MAP also with the aid of a tally counter. Cane yield at harvest was taken from the harvested stalks, weighed and expressed in t ha^{-1}. Whip smut was not induced artificially in the test cane genotypes as the trial site has been repeatedly cropped to known susceptible canes to Sporisorium scitamineum, (Wada et al. 2016), so were left to natural infection. Percent smutted stools and stalks were calculated by first counting the total number of stools and stalks in a plot using a tally counter. Then the number of smutted stools and stalks in the same plot was counted and expressed as a percentage of the total to determine the incidence of whip smut at 3, 6, 9, and 12 MAP. All data collected were subjected to analysis of variance (ANOVA). The means were separated using the Least Significant Difference (LSD) at a 5 % level of probability using the SAS version 9.2 statistical package (SAS, 2002).

Results

Weed dry weight was significantly lower in Bida local cane than NCS 001 cane at 3 and 9 MAP only (Table 1). However, under trash mulch, application of 9 t ha-1 at 3 MAP, 6 or 9 t ha-1 trash mulch at 6 and 9 MAP in 2016 and 9 t ha-1 trash mulch at 9 MAP in 2017 had significantly lower weed dry weight than the other lower rates. (Table 1). Results also showed that weed dry weight was significantly affected by the weed management practices such that, application of PE diuron + POE 3 – maize force herbicides at 3 and 6 MAP, PE diuron + POE 3 – maize force herbicides + 2 MHW at 9 MAP in 2016 and PE diuron + POE 3 – maize force herbicides at 9 MAP in 2017 recorded the lowest weed dry weight, while no weeding accounted for the highest weed dry weight (Table 1).

Table 1. Effects of sugarcane genotypes, trash mulch rate and weed management practices on weed dry weight at 3, 6 and 9 MAP in the 2016 and 2017 seasons.

	Weed dry weight (g m^{-1})					
	3MAP		6MAP		9MAP	
Treatment	2016	2017	2016	2017	2016	2017
Genotypes (S)						
Bida local	0.53	0.55	0.43	0.41	0.24	0.21
NCS 001	0.54	0.61	0.44	0.43	0.26	0.24
LSD (0.05)	0.006	0.003	0.20	0.12	0.76	0.62
Mulch rate (t ha^{-1}) (M)						
0	0.68	0.72	0.55	0.51	0.31	0.31
3	0.58	0.63	0.46	0.46	0.24	0.23
6	0.46	0.50	0.38	0.36	0.22	0.21
9	0.48	0.46	0.35	0.34	0.22	0.16
LSD (0.05)	0.012	0.014	0.026	0.03	0.81	0.63
Weed management (W)						
Weedy check	0.59	0.64	0.49	0.46	0.32	0.27
5 MHW	0.55	0.59	0.45	0.44	0.25	0.22
PE + POE + 2HW	0.52	0.57	0.42	0.41	0.22	0.23
PE + POE	0.48	0.52	0.38	0.37	0.20	0.18
LSD (0.05)	0.01	0.03	0.02	0.03	0.95	0.73
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, MAP- Months after planting

Smut incidence was significantly higher in Bida local cane than NCS 001 at 3 and 6 MAP in both years (Table 2). However, under trash mulch, smut incidence was highest in plots without mulching. Furthermore, the weedy check recorded higher smut incidence compared to other sugarcane plots given the other weed management practices (Table 2).

Table 2. Effects of sugarcane genotypes, trash mulch rate and weed management practices on percent Smut incidence at 3 and 6 MAP in the 2016 and 2017 seasons.

Treatment	% Smut incidence 3 MAP		6 MAP	
	2016	2017	2016	2017
Genotypes (S)				
Bida local	2.5	6.0	3.0	3.1
NCS 001	1.7	2.8	2.5	2.9
LSD (0.05)	0.2	1.1	0.3	0.4
Mulch rate (t ha^{-1}) (M)				
0	2.7	13.5	3.2	3.1
3	2.1	7.5	2.8	3.0
6	1.4	8.5	2.8	3.0
9	2.1	9.2	2.2	2.8
LSD (0.05)	0.2	1.5	0.4	0.6
Weed management (W)				
Weedy check	2.3	9.9	3.0	4.4
5 MHW	1.8	8.7	2.9	4.0
PE + POE + 2HW	2.0	9.6	2.7	2.5
PE + POE	2.3	9.4	2.4	0.9
LSD (0.05)	o.2	1.6	0.3	0.6
Interaction				
M x W	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, MAP- Months after planting

Table 3. Effects of sugarcane trash mulch and weed management practices on stalk height, girth, brix content, number of stool per plot , millable stalks and cane yield of sugarcane genotypes at 12 MAP in 2016 and 2017 seasons.

Treatment	Stalk height (cm)		Stalk girth (cm)		Brix content (%)		Number of Stools per plot		Millable stalks per stool		Cane yield (t ha^{-1})	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Genotypes (S)												
Bida local	146.4	172.5	3.05	3.27	16.49	16.74	9.17	17.63	3.01	3.29	52.12	57.24
NCS 001	178.6	201.9	2.63	2.68	18.28	18.29	11.75	22.17	5.51	5.33	82.27	66.18
LSD (0.05)	11.05	33.65	0.12	0.11	0.62	0.58	1.27	1.47	0.52	0.40	4.63	4.61
Mulch rate (tha^{-1})												
0	147.94	156.04	2.36	2.63	16.89	16.36	7.75	16.88	3.39	3.21	52.36	41.47
3	157.18	167.92	2.90	2.97	16.28	16.60	10.33	21.33	4.06	4.04	68.71	67.13
6	161.36	171.5	2.93	3.07	17.82	18.14	10.66	19.54	4.54	4.67	70.95	67.99
9	187.43	195.75	3.16	3.28	18.63	18.95	13.08	21.83	5.05	5.33	76.74	70.24
LSD (0.05)	5.43	5.85	0.06	0.06	0.31	0.49	1.79	2.09	0.73	0.57	2.82	2.55
Weed management (W)												
Weedy check	148.5	168.7	2.37	2.66	16.60	16.30	8.17	14.67	3.63	3.75	57.33	54.91
5 MHW	181.5	209.1	3.15	3.24	18.15	18.38	11.79	20.83	4.63	4.63	77.54	61.29
PE +POE + 2 HW	161.4	186.0	2.93	2.99	17.11	17.38	10.46	21.88	4.35	4.29	66.08	63.76
PE +POE	158.7	184.9	2.91	3.24	17.68	18.0	11.42	22.21	4.43	4.58	67.81	66.87
LSD (0.05)	15.63	20.03	0.17	0.16	1.29	0.82	1.79	2.09	0.73	0.57	8.36	5.23
Interaction												
M x W	NS	NS	NS	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.

significantly taller than the lower rates in each year of study (Table 3). Furthermore, 5 MHW consistently recorded taller cane plants than the other weed management practices in both years of the study (Table 3). Thicker sugarcanes were recorded in Bida local plots compared with that in NCS 001 plots in both years of study (Table 3). Furthermore, thicker sugarcanes were obtained from plots given 9 t ha^{-1} trash mulch compared to the lower rates in both years of the study (Table 3). Also, stalk girth was significantly thicker in plots treated with 5 MHW, but at par with the application of PE diuron + POE 3 – maize force plots in 2017 only (Table 3).Stalk height was significantly ($P<0.05$) different between the sugarcane genotypes in both years of study (Table 3).

The commercial genotype sugarcane, NCS 001 was significantly taller than the local chewing cane, Bida local. Sugarcane plots applied 9 t ha^{-1} mulch were Higher brix content was obtained in NCS 001 sugarcane compared with that from Bida local sugarcane in both years of study (Table 3). Furthermore, the highest brix content was found in sugarcane plants given 6 t ha^{-1}, but similar to that in 9 t ha^{-1} treated plots in both years. Also, 5 MHW and application of PE diuron + POE 3 – maize force herbicides in the two years of study, and PE diuron + POE 3 – maize force herbicides + 2 MHW in 2016 only recorded similar higher brix content compared to other sugarcane plants given the other weed management practices (Table 3).There was a significant interaction between trash mulch and weed management practice on brix content of sugarcane in 2017 where under 5 MHW, brix content was not significantly increased as mulch was increased from 0 to 9 t ha^{-1} (Table 4).

Table 4. Interaction effects between mulch rate and weed management practices on brix content at 12 MAP in 2016 and cane yield (t ha^{-1}) at 12 MAP in the 2016 and 2017 seasons.

	Weed management			
	Weedy check	5 MHW	PE + POE + 2	PE + POE
Mulch rate (t ha^{-1})		Brix content 2016		
0	13.52	17.87	16.0	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
SE±	6.43			
		Cane yield (t ha^{-1}) 2016		
0	24.0	57.67	50.61	47.38
3	38.80	76.83	55.97	51.20
6	54.35	69.58	57.87	65.10
9	71.18	75.50	69.73	73.72
SE±	9.09			
		2017		
0	13.33	48.05	39.05	48.38
3	60.57	62.09	52.19	67.24
6	58.86	60.95	67.57	66.67
9	62.81	77.14	71.43	59.24
SE±	9.03			

MHW- monthly hoe weeding, PE +POE +2 MHW- diuron at 2 kg a.i ha^{-1} (pre-emergence) + 3 – maize force at 179.2 g ha^{-1} (post-emergence) + 2 MHW, PE +POE - diuron at 2 kg a.i ha^{-1} (pre-emergence) + 3 – maize force at 179.2 g ha^{-1} (post-emergence)] only.

Application of 9 t ha^{-1} mulch in combination with 5 MHW, PE diuron + POE 3 – maize force herbicides + 2 MHW, or PE diuron + POE 3 – maize force herbicides recorded the highest brix content in this study.

The number of stools per plot varied significantly with weed management practices. Genotype NCS 001 produced more stools than Bida local in both years of study (Table 3). The highest number of stools was found in sugarcane plots given 9 t ha-1 mulch in both years. The 5 MHW and application of PE diuron + POE 3 – maize force herbicides in the two years of study, recorded a similar higher number of stools compared to sugarcane plots given the other weed management practices (Table 3).Genotype NCS 001 significantly produced more millable stalks than Bida local (Table 3). Sugarcane applied with 9 t ha-1 mulch recorded significantly higher millable stalks than the lower rates in each year of the study (Table 3). Weed management practices significantly affected the number of millable stalks per stool.

The application of 5 MHW produced more millable stalks in 2016 and 2017 seasons, which were similar to those of other weed management treatments. The weedy check consistently produced the lowest millable stalks throughout the study period. Cane yield was significantly higher in NCS 001 plots compared with Bida local in the two years of study (Table 3). Furthermore, the application of 9 t ha-1 mulch recorded significantly higher cane yield compared to plots applied with lower rates in both years. Application of 5 MHW produced higher cane yield in 2016 plant crop while cane yield of PE +POE and PE + POE + 2 MHW were at par. On the other hand, the application of PE +POE herbicide recorded the highest cane yield but was at par with PE + POE + 2 MHW treatments in 2017.

There was a significant interaction between mulch application rate and weed management practices on sugarcane yield in 2016. In spite of this, irrespective of the weed management practice in combination with 9 t ha-1 mulch, cane yield was higher and comparable to 5 MHW in combination with 3 or 6 t ha^{-1} mulch rates (Table 4). In 2017, also irrespective of weed management practice in combination with 3 or 9 t ha^{-1} mulch, cthanyield was significantly higher from all the weed management strategies in this study.

Discussion

The superiority of the Bida local genotype in reducing weed growth and producing thicker canes than the NCS 001 could be attributed to its morphological characteristics such as leaf canopy formation and its more robust nature which might have shaded weed seed germination and seedling growth. This finding is in agreement with the work of Takim et al. (2014).
who noted that sugarcane varieties vary in growth characteristics, which can in turn directly affect weed competition. Ahmed et al. (2014) also reported that local chewing canes are more robust than commercial canes.

The relatively low smut incidence observed in NCS 001 may be attributed to heavy residue production and better weed competitive ability which stimulate the release of chemicals for the inhibition of pathogens thus, reducing the chances of smut disease spread as reported by Chalker-Scott (2007). The Bida local chewing sugarcane is noted for its susceptibility to whip smut (Wada, 2018). Therefore, its higher smut incidence recorded in the present study is not surprising. The fear of the Bida local genotype totally being destroyed by whip smut forced this trial to be terminated at only the plant crop cycle in both years 2016 and 2017. The ratoon cycle of the study would have recorded dead stools from the Bida local genotype (Wada, 2018) leaving only the NCS 001 genotype for evaluation against the test weed management strategies in the present study.

The production of consistently taller sugarcane stalk, higher brix, and cane yield in plots with NCS 001 can be attributed to better crop growth in terms of internode length and tillering ability governed by its superior genetic potential and efficient use of applied inputs for improved growth and cane yield.

The present result agrees with the findings of Kuri and Chandrashekar (2015) who observed significantly taller millable cane, and longer internode with sugarcane genotype, CoSnk 07103 than the other genotypes, except Co92005 (G3) in their study. Furthermore, Ahmed et al. (2014) and Katia et al. (2019) also reported that among the sugarcane genotypes that exist, improved (or commercial canes) genotypes have thin stems that contain high sucrose and less water due to the varied morphological differences.

The observed increase in the number of stools and millable canes might also be attributed to a 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 Cheong and Teeluck (2015) and Gisele et al. (2017) who reported that variation in the number of stools per plot and number of millable canes could be attributed to varied variety morphology and weed suppression under the prevailing agro-ecological conditions.

The result of higher cane yield in this study was similar to the work of Mohammed et al. (2019) who recorded the highest cane yield with ILS 708-05 genotype compared to other genotypes tested. These authors also stated that high brix content and cane yield by a sugarcane genotype is a function of the higher genetic potential of the variety.

Thus, NCS 001 genotype recording more stalks or cane yield than Bida local is the result of its genetic potential being higher than Bida local, hence the differential yield attributes and yield recorded from this report among the treatments from the two test canes. In terms of trash mulch, the application of 9 t ha^{-1} significantly suppressed weeds at the most. At the high mulching rate, weeds might not have had a favorable environment for easy germination, faster growth and development. Trash mulch must have acted as a physical barrier, causing etiolation and stem weakening, thus making them more prone to mechanical damage.

The reduction of weed dry matter due to an increase in the application of trash mulch has been reported by Henrique et al. (2013), Kuri and Chandrashekar (2015) and Waghmere et al. (2018). The relatively low smut incidence observed under trash mulching could be the result of more moisture reserved, reduced evapotranspiration from the soil, suppression of weed germination, growth and development, and increased soil nutrient status. On the other hand, the high whip smut incidence recorded in sugarcane plots without mulching agrees with reports by other workers that dry environments favor whip smut invasion (Comstock, 2014; Wada et al 2016).

This significant mulching effect on plant crops is in agreement with the work of Ahmed et al. (2014) and Sanjeev et al. (2015), who reported that the higher the applied quantity of organic mulch, the more sustainability of the crop in the field. Also, in this study, 9 t ha^{-1} mulch application produced taller plants, thicker cane stalks, higher brix content, more stools and millable canes as well as high cane yield which was comparable to 6 t ha^{-1}. The increase in growth and yield attributes of sugarcane in this study could have been due to improved soil water conservation, cooler soil environment and effective weed management, which in turn might have improved soil fertility status from the addition of trash mulch at these higher rates (Flavio et al. 2013). The result is consistent with previous studies, in which the application of trash mulch at 6 to 9 t ha-1 enhanced cane yield of sugarcane (Concenco et al., 2016). Also, Kumar et al. (2015) reported that the application of trash mulch at 10 t ha^{-1} recorded the tallest plants, the highest number of tillers, millable canes, cane girth, average cane weight and cane yield. The maximum reduction of weed dry matter by PE diuron + POE 3 – maize force + 2 MHW and PE diuron + POE 3 – maize force could be attributed to effective desiccation and season-long weed management in sugarcane. This observation corroborates the findings of Choudhary and Singh (2016) who reported the need to apply pre-emergence and post-emergence herbicides for effective season-long weed management in sugarcane production. The relatively low smut incidence observed under weed management practices can be attributed to a decrease in weed dry matter caused by weakening of stems and roots, depletion of weed seed bank and better conditions for crop growth, hence good cane yield.

This is consistent with the findings of Singh et al. (2011) and Choudhary and Singh (2016). Also, in this study, the practice of 5 MHW produced taller stalks than all the other weed management practices, thicker canes which were comparable with PE diuron + POE 3 – maize force in 2017, higher brix content which was comparable to PE diuron + POE 3 – maize force + 2 MHW in 2016 and PE diuron + POE 3 – maize force; which suggest that these treatments provided good weed management and enhanced sugarcane growth and yield. Nadir et al. (2015) also reported that weed management treatments decreased weed growth and favorably enhanced yield contributing characteristics of sugarcane such as stalk height and girth, and brix content in their study. Zafar et al. (2010) reported taller and thicker sugarcane stalks in plots given monthly hoe weeding, which was comparable to the application of pre-emergence plus post-emergence herbicides. The higher cane yield from plots that were monthly hoe weeded five times in 2016 and the application of PE diuron + POE 3 – maize force in 2017, could be attributed to the effective reduction of weed growth which provided conditions for good crop growth and yield of sugarcane in the present study. Choudhary and Singh (2016) also reported that manual hoe weeding and application of PE + POE herbicides can effectively reduce weed growth and increase sugarcane growth and yield which is the thrust of the present work.

The reduction in weed dry matter, increase in brix content and production of higher cane yield was due to an increase in trash mulch application and reduction in weed growth, which in turn provided a favorable condition for sugarcane growth and yield. This is consistent with the findings of Chaudhari et al. (2016) in Maharashtra, India, who reported similar results on the interaction between trash mulching and weed management practices on weed dry matter production.

The interaction between trash mulch and weed management practices on brix content and cane yield showed that every increase in trash mulch from 0 to 9 t ha-1 resulted in a concomitant increase in brix content and cane yield in plots given 5 MHW or PE diuron + POE 3-maize force + 2 MHW. This could be due to changes in moisture, light and soil temperature, increased microbial activities, organic matter, soil chemical properties and decrease in weed infestation provided by mulching which translated into improved growth and yield of the two test canes. Ahmed et al. (2014) in Badeggi, Nigeria and Flavio et al. (2013) in Sao Paulo, Brazil reported similar results on interaction between trash mulching and weed management practices of sugarcane.

Conclusions

This study has shown that the application of 9 t ha-1 trash mulch with 5 MHW or PE diuron plus POE 3 – maize force plus 2 MHW or PE diuron plus POE 3 – maize force effectively managed weeds, whip smut incidence, increased growth and cane yield of sugarcane, especially NCS 001 in this agroecology of Nigeria.

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