Available online at www.worldnewsnaturalsciences.com

World News of Natural Sciences

An International Scientific Journal

WNOFNS 48 (2023) 28-39 EISSN 2543-5426

Intercropping Impact on Weed Dry Matter, Soil C and N, Sugar Quality and Sugarcane (*Saccharum officinarum* L.) Productivity

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ABSTRACT

The effects of intercropping on weed dry matter, soil C and N, sugar quality and sugarcane productivity were investigated at Badeggi, Nigeria in 2016 and 2017. The results revealed that application of Sugarcane + Groundnut intercropping produced lower weed dry matter comparable to Sugarcane + Soybean intercropping which significantly increased growth and yield attributes of sugarcane. Application of Sugarcane + Groundnut intercropping, resulted in a comparable germination count, Tiller count, plant and stalk height to Soybean intercropping. Similarly, Sugarcane + Groundnut intercropping and Soybean intercropping produced comparable stalk height and brix content. Also, Sugarcane + Groundnut intercropping generated more millable canes and stools per plot. Application of Sugarcane + Groundnut intercropping proved equally effective as Soybean intercropping in contributing the highest soil C and N and cane yield. In the same way, Sugarcane + Groundnut intercropping and Soybean intercropping produced comparable sucrose and glucose content. Lower weed dry matter was found in Sugarcane + Groundnut intercropping, and taller plant and stalks, girth, brix content, millable cane, stools, sucrose, glucose content. and cane yield were observed in Sugarcane + Groundnut intercropping. In conclusion, application of Sugarcane + Groundnut intercropping or Soybean intercropping effectively controlled weeds, increased Soil C and N, plant and stalk height, girth, brix content, millable cane, stools and cane yield of sugarcane.

Keywords**:** Intercropping, Plant crop, Sugarcane, Sugar quality, Weed dry matter, *Saccharum officinarum*, *Gramineae*

(Received 21 February 2023; Accepted 10 March 2023; Date of Publication 11 March 2023)

1. INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) family *Gramineae* (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 (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 of sugarcane (Bassey *et al*. 2021).

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 *et al.* 2015; Mohammed *et al*. 2017).

One potential way to improve sugarcane production among small land holders and meet demand for sugar is by sugarcane intercropping. Sugarcane is a long duration and widely spaced crop in comparison with other field crops; it offers a great scope for using its interspaces by growing short duration crops. In general, sugarcane has a juvenile period of 100-120 days, which can accommodate intercrops of arable crop and can be widely practiced (Rasool *et al*. 2011 and Geetha *et al*. (2015).

The wide space (1 – 1.5 m) available between two rows of sugarcane, long duration for sprouting (21–30 days), initially slow rate of growth and its ability to compensate for any loss of tillers due to intercropping, has helped successful intercropping of cereals, legumes, vegetables and spices in plant and ratoon crop (Priyanka *et al*. 2019). Sugarcane intercropping can be efficient and economically viable in increasing production per unit area and ensure judicious use of resources with increase in farmer's economy. For example in Egypt, intercropping sugarcane with soybean significantly increase sugarcane yield and sugar quality (Morsy *et al*. 2017).

In India, Singh *et al*. (2017) reported significant yield increase when Potatoes was intercropped with sugarcane. In Nigeria, intercropping sugarcane with arable crops has been recommended for optimum sugarcane production (Gana, 2013). In Nigeria, research information on industrial sugarcane when intercropped with arable crops is scarce. Hence, the objectives of this study were to evaluate the effects of industrial sugarcane intercropping on weed dry matter, sugar quality, net farm income and sugarcane productivity.

2. MATERIALS AND METHODS

A field trial was conducted at the upland sugarcane experimental field of National Cereals Research Institute, Badeggi (Lat. 9°45' N, Long. 6°07' E and 89 m above sea level) in the southern Guinea savanna agro-ecological zone of Nigeria in 2016 and 2017 wet and dry season. The total rainfall during the experimental period was 1504.1 mm in 2016 and 1045.4 mm in 2017 while the mean air temperature was 35 to 38 °C in 2016 and 34 to 36 °C in 2017.

Composite soil samples were taken before field establishment from ten spots along a diagonal and at harvest from each treatment plot from 0 to 15 cm depth, and subjected to routine analyses. Particle size analysis was done by the Bouyoucos hydrometer method (Gee and Or 2002). Soil organic carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson *et al*. 1996). Total N was determined by the micro—Kjeldahl digestion method (Bremner and Mulvaney 1982). The Olsen method was used to determine available phosphorus, and flame photometry for exchangeable potassium (Okalebo *et al.* 2002).

Soil pH was determined in 1:2 soil–water ratio using digital electronic pH meter.

Before cultivation, the vegetative cover of the experimental site was manually cleared, ploughed and harrowed with a tractor. Thereafter, the land was marked out into plots with bunds at the edges for water retention. Gross plot size was 6 × 5 m (30 m^2) consisting of 5 sugarcane rows, and four rows of component crops, while net plot size was 5 × 3 m (15 m^2).Sugarcane was planted at 1.5 m inter – row spacing a month before the component species were planted in between at 0.75 m inter – row spacing. 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, planted continuously end-to-end without intra-row spacing in shallow sunken bed. The NPK fertilizer was applied at 150 kg N, 60 kg P_2O_5 and 90 kg K_2O in equal halves at planting and 10 WAP. Rainfall was supplemented with irrigation in May which was the establishment of the rainy season.

The treatments consisted of Short kaura, Beniseed, Soybean and Groundnut were intercropped with sugarcane along with sole sugarcane arranged in a randomized complete block design with three replications.

Weed species samples in each plot were collected froma 1 × 1 m^2 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 samples were oven dried at 80 °C to a constant weight and weighed to determine the dry matter in g per m^2.

Sugarcane germination (%) was taken by counting the number of sprouted buds per plot at three weeks after planting and expressed as follows:

$$\text{Germination percentage} = \frac{Number of sprouted buds per net plot}{Total number of buds on the setts planted per plot} \times 100$$

Number of tillers per plot was taken by counting the number of axillary tillers per plot at two months after planting. Plant height was measured using meter rule from the base of the plant to the top of the uppermost leaf at 3 and 6 MAP and expressed in centimeters. Stalk height was measured using meter rule from the base of the plant to the uppermost node at 6, 9 and 12 MAP and expressed in centimeters. Stalk girth was measured using Vernier caliper from the middle of the plant at 8, 10 and 12 MAP and expressed in centimeters. Percent brix was measured using hand refractormeter from the base of the plant at 9 and 12 MAP to determine the level of soluble sugar. Number of sugarcane stools per plot was taken by counting the number of stools at 12 MAP or months after ratooning (MAR). Number of millable stalk per stool was taken by counting the number of stalks at 12 MAP or months after ratooning (MAR).

Stalk (Cane) yield at harvest was taken from the harvested stalks in the net plot, tied into bundles and weighed (tons ha^{-1}).

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.

3. RESULTS

The soil was sandy loam in texture with soil pH moderately acidic. In general, the soils were low in nitrogen, phosphorus and other essential nutrients (Table 1).

Table 1. Initial soil physical and chemical properties in at Badeggi in 2016

Soil properties	Value
Sand (g kg^{-1})	722
Silt (g kg^{-1})	135
Clay (g kg^{-1})	143
Textural class	Sandy loam
pH (H_2O) (g kg^{-1})	5.80
Organic Carbon (g kg^{-1})	2.37
Total Nitrogen (g kg^{-1})	0.06
Available Phosphorus (mg kg^{-1})	20.29
Ca^{2+} (cmol kg^{-1})	2.48
Mg^{2+} (cmol kg^{-1})	1.38
K^{+} (cmol kg^{-1})	0.16
Na^{+} (cmol kg^{-1})	0.09
Exchangeable acidity(cmol kg^{-1})	1.03
ECEC (cmol kg^{-1})	5.14

Analyzed at National Cereals Research Institute Laboratory

Weed dry weight was significantly ($P < 0.05$)lower in Sugarcane + Groundnut intercropping at 3 and 6 MAP in 2016, and Sugarcane + Soybean intercropping had lower weed dry weight only at 6 MAP than the other treatments (Table 2).

Table 2. Sugarcane intercropping effects on Weed dry weight (g m^{-2})

Treatments	Weed dry weight (g m^{-2})					
	3 MAP		6 MAP		9 MAP	
	2016	2017	2016	2017	2016	2017
Sugarcane + Sole	0.68	0.60	0.58	0.50	0.47	0.41
Sugarcane + Short kaura	0.64	0.63	0.52	0.51	0.33	0.38
Sugarcane + Beniseed	0.71	0.63	0.62	0.54	0.39	0.42
Sugarcane + Soybean	0.62	0.60	0.51	0.51	0.20	0.20
Sugarcane + Groundnut	0.61	0.63	0.53	0.48	0.33	0.33
LSD (0.05)	0.1	0.1	0.2	0.1	0.2	0.1

MAP – Months after planting, LSD – Least significant difference.

Germination count (%) was significantly ($P < 0.05$) different between the sugarcane intercrops in both year of study (Table 3). Sugarcane + Groundnut intercropping had significantly higher germination percentage than the other intercrops in each year of study (Table 3). Furthermore, Sugarcane + Groundnut intercropping produced more tillers than the other intercrops in each year of study (Table 3). Taller sugarcane were obtained in Sugarcane + Groundnut intercropping than the other intercrops in each year of study (Table 3). Stalk height and internode length were significantly ($P < 0.05$) different between the sugarcane intercrops in both year of study (Table 3). Sugarcane + Groundnut intercropping had consistently higher soil C and N than other intercrops in both years of study (Table 3).

Table 3. Sugarcane intercropping effects on some growth parameters of sugarcane

Treatments	Germination count (%)		Tiller count/ plot		Plant height (cm)		Stalk height (cm)		Soil C (g kg^{-1})		Soil N (g kg^{-1})	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Sugarcane + Sole	53.8	66.7	36.5	49.3	150.4	176.4	119.9	150.2	2.41	3.23	0.12	0.17
Sugarcane + Short kaura	50.5	67.0	35.8	47.7	144.8	184.5	118.6	155.3	2.44	3.36	0.15	0.19

Sugarcane + Beniseed	50.9	70.3	36.3	58.7	141.7	176.1	119.5	160.2	2.45	3.37	0.15	0.18
Sugarcane + Soybean	54.0	72.0	39.3	64.7	154.2	190.6	127.4	166.9	2.47	3.39	0.16	0.19
Sugarcane + Groundnut	59.0	83.3	43.2	67.0	164.8	198.3	136.3	175.5	2.51	3.45	0.19	0.24
LSD (0.05)	5.8	5.2	6.5	3.9	15.0	4.4	14.8	3.4	0.02	o.o1	0.01	0.02

LSD – Least significant difference

Thicker sugarcane was recorded in Sugarcane + Groundnut intercropping compared with that in other intercrops in both years of study (Table 4). Furthermore, higher brix content was obtained in Sugarcane + Groundnut intercropping compared with that in other intercrops in both years of study (Table 4). Millable canes and Stools were significantly ($P < 0.05$) different between the sugarcane intercrops in both year of study (Table 4). Sugarcane + Groundnut intercropping consistently produced more millable canes and stools other intercrops in both years of study (Table 4). Cane yield of sugarcane was significantly higher in Sugarcane + Groundnut intercropping compared with the other intercrops in both years of study (Table 4). Similarly, Sugarcane + Groundnut intercropping consistently produced higher net farm income than the other intercrops in both year of study (Table 4). Net farm income was consistently higher in Sugarcane + Groundnut intercropping plot compared with the other intercrops in both years of study (Table 4).

Table 4. Sugarcane intercropping effects on some yield parameters of sugarcane

Treatments	Stalk girth (cm)		Brix (%)		Millable cane/ Plot		Stools/Plot		Cane yield (t ha^{-1})		Net farm income (Naira ha^{-1})	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Sugarcane + Sole	3.1	2.7	14.9	18.1	73.9	94.7	15.9	14.3	66.1	59.9	2577	3204.7
Sugarcane + Short kaura	2.9	2.7	14.5	18.2	71.5	94.9	17.6	15.3	71.7	66.4	5493	5750.0
Sugarcane + Beniseed	3.2	2.8	15.5	19.2	80.0	98.7	16.7	17.0	72.1	74.2	4220	8462.0

Sugarcane + Soybean	3.1	2.9	15.8	20.4	83.7	100.0	17.2	16.6	81.3	77.2	9280	9758.1
Sugarcane + Groundnut	3.5	3.5	18.9	21.0	90.5	119.1	19.7	20.0	87.6	85.8	16347	13261.3
LSD (0.05)	0.3	0.2	1.2	0.4	2.5	2.4	3.5	1.8	12.8	0.9	6401.8	1269.7

LSD – Least significant difference

Sugarcane moisture content was significantly (P < 0.05) different between the sugarcane intercrops in both year of study (Table 5). Sugarcane + Groundnut intercropping had significantly higher moisture content than the other intercrops in each year of study (Table 5).Sole sugarcane produced more fibre than the other intercrops in each year of study (Table 5). Higher sucrose content in sugarcane were obtained in Sugarcane + Groundnut intercropping compared with that in other intercrops in 2016 only (Table 5).

Table 5. Sugarcane intercropping effects on sugar quality of sugarcane

Treatments	Moisture		Fibre		Sucrose		Glucose		Polarity		Purity	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Sugarcane + Sole	62.1	52.0	13.6	12.7	18.9	21.7	23.7	23.5	21.0	20.2	86.9	12.0
Sugarcane + Short kaura	65.2	54.7	12.5	11.7	20.2	19.7	25.3	25.0	18.5	18.6	82.2	11.2
Sugarcane + Beniseed	66.2	55.7	11.9	10.7	20.2	20.0	25.2	25.2	18.5	19.3	84.5	11.3
Sugarcane + Soybean	63.9	53.7	13.4	12.3	21.6	20.3	27.0	26.6	19.7	23.3	86.9	11.9
Sugarcane + Groundnut	69.4	59.0	8.8	9.3	22.8	18.7	28.5	27.7	17.5	18.2	79.8	11.1
LSD (0.05)	4.7	5.2	4.2	2.4	4.1	1.5	4.2	4.3	3.4	3.9	10.9	1.8

LSD – Least significant difference

Glucose content was significantly higher in Sugarcane + Groundnut intercropping compared with the other intercrops in both years of study (Table 5). The purest form of sugarcane was obtained in sole sugarcane and sugarcane + soybean intercrop in 2016 only (Table 5).

4. DISCUSSION

The low nutrient status of initial soil physical and chemical properties of the experimental site could be attributed to long time cultivation of the field with frequent usage of inorganic fertilizers which could help in soil improvement. Gana (2013) reported that 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 inputs due to leaching and erosion. The author therefore recommended the recycling of organic residues as means of improving soil productive capacity and reducing dependence on mineral fertilizer.

The reduction in weed dry weighty caused by Groundnut and Soybean intercropping could be due to coverage which interferes with weed seeds germination, mainly due to changes in moisture, light and soil temperature, which are main controllers of seed dormancy and germination. This in turn affects seedling development by acting as a physical barrier, causing etiolation and stems weakening, making them more prone to mechanical damage. Furthermore, chemical issues may arise from changes in the C/N ratio and allelopathy, as well as creating favorable environment for insects and microorganisms, which can either host on weeds or feed from seeds. This confirms the findings of Martin-Guay *et al.* (2018) and Bassey *et al.* (2019a and b), who found, significant variation among cereal/legume intercropping to reduction in weed dry matter.

This result could be attributed to decreased photosynthesis caused by loss of chlorophyll in leaves and stems, weakening of stems and root, and the loss of the weed seeds in soil, which translated to effective season long weed control in sugarcane. These findings are consistent with previous studies of Singh *et al*. (2011), Zhang *et al.* (2013), Nadir *et al*. (2015) and Choudhary and Singh (2016), who indicated that, weed management in sugarcane can be achieved by cultural methods.

Finally, these findings might also be attributed to legumes (Groundnut and Soybean) acting as a trap or catch crop and the shading effect from legume canopy. Our findings is in agreement with various studies that shown that intercropping cereals, mainly with legumes such as cowpea (*Vigna unguiculata*), peanut (*Arachis hypogaea*) and green gram (*Vigna radiata*) can reduce the number of weed plants (Li *et al*. 2016; Bassey *et al*. 2019a).

The high germination percentage, tiller count, plant and stalk height obtained from sugarcane intercropped with legume may be attributed to the nitrogen supplied by the legume component crop (Groundnut) through nitrogen fixation and mineralization of the decomposed incorporated herbage. Gana (2013) reported beneficial effects of legumes on sugarcane growth parameters (Germination count, tiller, stalk height and internode length) from incorporated legumes at Badeggi in Nigeria

Soil organic carbon (SOC) and soil total nitrogen (STN) were increased by Groundnut and Soybean intercropping. This can be attributed to the high C/N ratio of the legume residue which ensure a slow rate of mineralization of the residue, with consequent increase in SOC. The significant effects of intercropping legumes on SOC and STN might be due to dead leaves and roots added to the soil. The immobilization of N as a result of the high C/N ratio of the residues could be responsible for the high STN. Our finding was in agreement with those of Bassey *et al*. (2019b), who noted an appreciable increase in soil fertility in crop mixture, involving certain tropical legumes after cropping. They adduced the increase in soil fertility to the ability of legumes to fix large quantities of nitrogen into the soil. The inclusion of legumes in many crop mixtures had been reported to include improvement in N status of the soil through nitrogen fixation, its short lifespan, as well as its ability to cover the ground, with resultant decreases in the incidence of weed infestation and soil erosion (Bassey *et al*., 2021).

The positive response (increase) observed in this study for stalk girth, brix content, millable canes, number of stools and cane yield due to sugarcane intercropped with groundnut could probably be attributed to incorporation of residues resulting in high SOC. Increase in soil organic matter level might have resulted in increase in soil microbial activity, soil fertility, nutrient supply, porosity, permeability and thus, soil productivity (Yusuf *et al*., 2009; Bassey *et al*., 2019c). The findings obtained are consistent with that of other workers in the same savanna agroecological zone of Nigeria (Afolabi *et al*., 2017). The high yield obtained in the study area might be attributed to adequate moisture and other optimum growth factors obtained in this study (Mohammed *et al*., 2017).

The variation in sugar quality for moisture, sucrose and glucose could be attributed to heavy tillering, quick canopy formation and weed suppression which were enhanced by incorporation of legume residues resulting in high SOC under the prevailing agro-ecological conditions. These results are in line with those of Rasool *et al*. (2011) and Geetha *et al*. (2015) who found significant variation in sugar quality for different legumes/ sugarcane intercropping. The observed increase in sucrose and glucose 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 Cheong and Teeluck (2015) and Gisele *et 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.

5. CONLCUSION

The study has shown that the application of Groundnut or Soybean as intercrops for sugarcane effectively controlled weeds, increased sugar quality, soil C and N, growth and cane yield of sugarcane in this agroecology of Nigeria.

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