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Agronomic Performances and Ratoon-ability of Sugarcane (*Saccharum officinarum* L.) Genotypes in Forest-Savannah-Transition Agro-ecology

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ABSTRACT

Testing for cane and sucrose production potentials in more than one crop under less suitable condition is important to improve sugarcane's productivity. Thus, 12 sugarcane breeding lines were evaluated for agronomic performances and ratoon-ability in Forest-Savannah-Transition agro-ecology for two years. The trial was laid out in randomized complete block design with three replicates. Plant stands were counted at 3, 8 and 12 weeks after planting (WAP). Millable stalks (MLS) were sampled for brix percentage (BP) at 36, 40, 44 and 52 WAP. Cane stalks were harvested at 52 WAP when internodes and yield data were taken. The data collected were subjected to analysis of variance separately and combined for plant and ratoon crops. Means were separated using Least Significant Difference between crops and Duncan Multiple Ranged Test within crops. Significant differences exited in genotypes, crops and genotypes × crops for germination counts (GC), tiller counts (TC), stem diameter (STD), total stalk counts (TSC), internode length (INL), total stalk weight (TSW), MLS and flower traits. B70607 had highest GC, TCs and TSC; Hat-4 and EBON-006 had highest STD while Akwa-005, CO1001, IMO-002 and TRITON were among those with highest stalk height. The B70607, DB37/145, F141, Hat-4 and IMO-002 had highest TSW in plant crop while Akwa 005, B70607, CO1001, EBON-006, Hat-4, IMO-002 and TRITON had the highest in ratoon crop. Brix percentage differed for plant and ratoon crops at 36 and 52 WAP, but effects of genotype × crop were significant in all the sample periods. Genotype Cp65-357 had highest BP across the sampling periods. Performance of the ratoon crop at the formative stage was higher than that of the plant crop. Millable stalk was 20% and 14% of TC and TSC, respectively. B70607, IMO-002 and Hat-4 are suitable for both plant and ratoon crops while DB 37/145, Hat-4, IMO-002 and TRITON are identified for breeding purposes. Cp65-357 and CO1001 may be considered for higher ratoon-ability in more than one ratoon crops for their high sucrose content.

Key words: Adaptability, brix, ratoon crop, sucrose, sugarcane.

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a tropical and subtropical industrial crop that matures between eight and 12 months depending on cultivar. It belongs to the family Poaceae (Rehm and Espig, 1991), and it is distinguished by sugar accumulation which attracted the attention of early man on its domestication and improvement. Mature cane which may be green, yellow, purplish or reddish brown are considered ripe when its sugar content is at its maximum (Onwueme and Sinha, 2003). Nigeria is an important producer of sugarcane with a land potential of over 500,000 ha where mean cane yield is between 40 and 50 t ha^{-1}. The country is capable of producing cane that can be processed into about 3 million metric tonnes of sugar (NSDC, 2003). Girei (2012); Aina et al. (2015) reported about 84% returns is realizable on short run on farmers' investments on the crop in Nigeria.

Sugarcane can be rotated or inter-cropped with other crops where there are adequate sources of water. Like other C_4 plants, the long sunshine hours and intensity support the high yield potentials of sugarcane. Water requirement of the crop is high. In most growing areas, sugarcane needs about 1500-1800 mm rain, but 2500 mm or more may be required in hot dry areas (Rehm and Espig, 1991). Water is supplemented through irrigation to enhance production where there is shortage of rainfall. It is mostly cultivation in the naturally flooded areas of savannah agro-ecologies of Nigeria to take advantage of high sunshine, thus irrigation is imperative. Cost of irrigation adds to the total cost of production which consequently reduces the profits accruable to the farmers. Despite higher rainfall in the Rainforest-Savannah-Transition agro-ecological zone, sugarcane production may be impaired by the lower sunshine compared to savannah agro-ecological zones.

Ratooning is a common practice in sugarcane production throughout the world (Sundara, 2008). Ratoon-ability is important in many sugarcane growing countries to decide the suitability of cultivars for commercial use because of the high cost of establishing new farms. Yield potentials of a cultivar has been observed to depend on its ability to give more profitable ratoons (Chapman et al., 1992). The yield from ratoon crops can be higher than that from the plant crop because the vegetative period is often shorter (Rehm and Espig, 1991). However, decline in cane yield in successive ratoons is common. Low yield from ratoon crops of sugarcane in the tropics is due to poor sprouting of stubbles. Poor sprouting as well as irregular and continuous tillering during entire period of the crop results in about 60% mortality of tillers and thus less millable canes at harvest.

Improvement of weight of canes, sugar contents and climatic adaptation (short and long vegetative periods as well as drought tolerance) are some of the goals of sugarcane breeding. Sugarcane breeding also target the improvement of the ability to regrow (Rehm and Espig, 1991). One strategy of achieving these is to evaluate available genotypes in established areas or introduce improved genotypes. Besides, lower average cane productivity is caused by the yield decline in ratoon crops despite the use of the high yielding varieties and improved cane production technology (Gomathi et al., 2013). Evaluation of advanced breeding lines of the crop in an agro-ecology characterized with low sunshine but moderate rainfall is imperative. This will expand area of cultivation thereby increasing production of the crop. Therefore, this study evaluated 12 sugarcane genotypes for growth and yield performance, ratoon-ability and sucrose accumulation in a Forest-Savannah-Transition agro-ecology. Promising genotypes are expected to possess high yield, sucrose quality and ratoon-ability.

MATERIALS AND METHODS

Experimental materials and their sources

The experimental materials comprising of 12 genotypes of sugarcane were obtained from University of Ilorin Sugar Research Institute, Ilorin, Nigeria. They were evaluated in Ibadan representing a Forest-Savannah-Transition agro-ecology of Nigeria from 2013 to 2014. Total amount of rainfall at the experimental site were 1921.9 cm and 1836.7 cm for 2013 and 2014, respectively while mean temperature was 26.6 °C in 2013 and 25.7 °C in

2014. The experimental field was irrigated to take care of the water shortage when required.

Field layout and agronomy

The experiment was laid out in a randomized complete block design with three replicates. Each plot comprised of four rows, 5 m long and 1.5 m width (4 rows × 5 m × 1.5 m) representing unit plot size of 36 m^2. The plots were separated by 3m and the replicates were 4.5 m apart. The main planting in the first year, 2013, was termed plant crop while the first ratoon in 2014 was the ratoon crop in this study. Pest and disease free six months old cane setts that had three eyes each were planted by laying horizontally end-to-end in rows in the ploughed and harrowed field. NPK fertilizer was applied at the rate of 150 kg N, 60 kg P and 90 kg K in two equal split doses at planting and 10 WAP. The plots were kept weed free throughout the trial by applying herbicide as pre-emergence, at 5.0 l ha^{-1} each of paraquat (N, N'-dimethyl-4, 4'-bipyridinuim dichloride) and atrazine (2-Chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine), 2 days after planting with two hoe weeding operations at 4 and 12 WAP. Stalks of the canes were harvested from the middle two rows of each plot at 52 WAP by cutting from the base, 5cm above ground.

Data collection and analysis

Total stands per plot was counted at 3, 8 and 12 WAP as germination count (GC), Tiller count at 8 WAP (TC_8) and tiller count at 12 WAP (TC_{12}). Ten randomly selected millable stalks were sampled for BP at 36, 40, 44 WAP and 52 WAP (harvest brix) using hand refractometer (Hundioto, 2009). Height, diameter and weight of stalk were taken at harvest. Stalk height (SHT) was taken from the ground to the top visible dew-lap leaf using metre rule. Stalk diameter (STD) was taken using a pair of venier callipers at the base of the cane. Harvested cane stalks were bundled per plot and weighed as total stalk weight (TSW) using weighing scale. Millable stalk (MLS) and internodes were counted (NND) while length of internodes (INL) were measured with metre rule at harvest.

Data collected were analyzed separately for plant crop and ratoon crop using analysis of variance (ANOVA) with (SAS Institute, 2009). The data were pooled over the two years and also subjected to ANOVA. Means separation were conducted using Least Significant Difference wherever significant differences were detected in the F-test between crops while Duncan Multiple Range Test was used to separate means among genotypes within crops.

RESULTS

Establishment and formative growth of the sugarcane genotypes in plant and ratoon crops

There were significant differences in GC, TC_8, TC_{12} and TSC due to effects of genotype and crops (Table 1). Mean values for the traits were consistently higher in the ratoon crop than the plant crop. There was no significant difference due to crops in B61208, DB37/145 and EBON-006 for GC. The GC ranged from 13.7 in Cp65-357 to 44.7 in DB37/145 for the plant crop while it ranged from 22.7 in EBON-006 to 264.7 in B70607 for ratoon crop. Significant variation existed among the genotypes due to crops for TC_8, TC_{12} and TSC. The TSC ranged from 26.3 in EBON-006 to 90.0 in IMO-002 in plant crop while it ranged from 33.0 in EBON-006 to 117.5 in CO1001. Table 1 shows ranges for other growth traits at the formative growth phase of each cultivar of the crop.

Vegetative growth of sugarcane genotypes evaluated in plant and first ratoon crops

Significant variation due to crop existed for INL and TSW only (Table 2) with higher values in the ratoon crop than the plant crop. However, various significant variation existed for all the traits among the genotypes within and across crops. Coefficients of variation (CVs) for the traits ranged from 6.36 % for STD in plant crop to 22.42 % for TSW in ratoon crop.

Table 1. Establishment and formative growth of sugarcane genotypes evaluated in plant and ratoon crops

Genotype	Germination count at 3 WAP		Tiller count at 8 WAP		Tiller count at 12 WAP		Total stalk count at 54 WAP	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
Akwa-005	26.0	101.3**	44.0	146.0**	22.0	68.7*	48.3	77.5*
B61208	23.7	25.7ns	51.7	109.7**	25.7	53.7*	44.7	94.5*
B70607	41.0	264.7**	110.3	293.0**	64.7	107.3*	80.0	111.7*
CO1001	28.3	171.0**	53.0	242.7**	41.3	87.7*	48.3	117.5*
Co504	24.0	45.0*	60.3	90.7*	30.3	52.0*	41.7	76.0*
Cp65-357	13.7	100.0*	19.0	153.0**	14.0	44.0*	26.3	71.5*
DB 37/145	44.7	46.0ns	45.0	119.7**	25.0	55.7*	46.7	54.0*
EBON-006	19.7	22.7ns	42.7	60.7*	19.0	36.0*	26.3	33.0*
F141	22.7	175.7**	50.0	228.3**	36.7	54.7*	72.7	97.0*
Hat-4	29.3	89.7**	51.0	122.0**	23.3	41.0*	42.0	67.5*
IMO-002	20.3	116.7**	49.3	187.0**	31.0	105.0*	90.0	107.0*
TRITON	42.0	126.7**	109.7	229.7**	39.7	51.7*	67.3	90.5*
Statistics								
Mean	28.0b	107.1a	57.2b	165.2a	31.1b	62.3a	54.5b	83.1a
CV (%)	22.5	25.2	20.8	19.5	31.8	33.8	26.2	32.1
LSD	10.3	45.2	20.2	54.4	16.8	38.3	24.2	45.1
Mean square	387.0***	15710.1***	2121.7***	14993.0***	541.4**	2142.2**	1212.8**	1845.0*

in a Forest-Savannah-Transition agro-ecology in 2013 and 2014.

Means with different alphabets between crops were significantly different.

CV, LSD, ns, *, ** are coefficient of variation, least significant different, not significant, significant at P<0.05 and 0.01, respectively.

Table 2. Vegetative growth and yield components of sugarcane genotypes evaluated in plant and ratoon in a Forest-Savannah-Transition agro-ecology in 2013 and 2014

Genotype	Stalk height (m)		Stalk diameter (cm)		Internode per plant (no.)		Internode length (cm)		Millable stalk (no.)		Total weight of stalk (kg/plot)	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
Akwa-005	3.01	2.85^{ns}	2.79	2.60^{ns}	21.3	20.00^{ns}	12.65	16.20*	7.67	9.00^{ns}	49.88	90.00*
B61208	2.40	1.94*	2.67	2.58^{ns}	21.3	19.67^{ns}	11.63	12.90^{ns}	12.67	8.67*	40.80	54.60^{ns}
B70607	2.49	2.20^{ns}	2.20	1.92*	18.3	18.00^{ns}	11.52	14.80*	11.00	12.67^{ns}	52.78	90.60*
CO1001	3.23	2.79*	2.66	2.29*	21.7	24.33*	14.60	18.40*	10.00	13.00*	44.43	100.60*
Co504	2.89	2.40^{ns}	2.88	2.25*	24.7	18.67*	10.30	13.00*	10.67	9.67^{ns}	44.98	87.67*
Cp65-357	1.87	1.88^{ns}	2.38	2.40^{ns}	19.3	15.00*	9.72	13.50*	7.33	10.00*	34.72	37.20^{ns}
DB 37/145	2.78	2.60^{ns}	2.99	2.40^{ns}	20.7	23.67*	12.39	14.37*	9.00	7.00^{ns}	65.49	61.50^{ns}
EBON-006	2.55	2.15^{ns}	3.07	2.67*	20.0	18.00*	10.60	13.77*	11.00	7.67*	32.79	88.00*
F141	2.40	2.26^{ns}	2.21	1.90*	21.3	18.67*	11.30	12.20^{ns}	9.67	15.67*	53.70	47.27^{ns}
Hat-4	2.87	2.05^{ns}	3.39	2.80*	21.3	22.00^{ns}	13.80	12.47^{ns}	6.67	6.00^{ns}	75.70	68.50^{ns}
IMO-002	3.17	2.70*	3.00	2.29*	23.3	18.67*	14.79	14.00^{ns}	7.33	10.67*	66.15	94.50*
TRITON	3.39	2.55*	2.40	2.71*	23.3	20.67*	12.18	17.80*	8.33	7.00^{ns}	48.45	103.50*
Statistics												
Mean	2.75	2.37^{ns}	2.72	2.48^{ns}	21.4	19.78^{ns}	12.12	17.20*	9.28	9.75^{ns}	50.82	76.99*
CV (%)	17.87	6.49	6.36	7.08	8.37	8.28	11.19	22.02	13.97	14.80	21.83	22.42
LSD	0.76	0.26	0.29	0.33	2.72	3.02	2.30	2.07	2.19	2.44	18.78	29.23
Mean square	11.46^{ns}	0.33***	0.42***	0.42***	9.4*	20.32***	7.94*	244.05***	10.35***	24.61***	503.91*	1482.70*

CV, LSD, ^{ns}, *, **, are coefficient of variation, least significant different, not significant, significant at $P<0.05$ and 0.01, respectively.

Table 2 also shows that Cp65-357 had the least SHT (1.87 m) while Akwa-005, CO1001, IMO-002 and TRITON were among those with highest SHT (greater than 3.00 m) in the plant crop. The EBON-006, Hat-4 and IMO-002 were among the best genotypes with respect to STD. They had equal to or greater than 3.00 cm in the plant crop. None of the genotypes had up to 3.00 m for SHT or 3.00 cm for STD in the ratoon crop. The Co504 had the highest NND in the plant crop while CO1001 had the highest in the ratoon crop. Cultivar Cp65-357 had the least INL and MLS in the plant crop while Hat-4 was among those that had least values for the two traits in the ratoon crop. Akwa-005, B70607, Co504, DB37/145, Hat-4 and TRITON were significantly similar for the MLS in the two crops. The B70607, DB37/145, F141, Hat-4 and IMO-002 had highest TSW in the plant crop while Akwa-005, B70607, CO1001, EBON-006, IMO-002 and TRITON had highest in TSW in ratoon crop in 2014.

Considering the performance across crops, the effects of genotypes were significant ($P < 0.001$) for all the traits except SHT and INL (Table 2). The effects were not significant for SHT but for INL ($P<0.05$) in the plant crop. Only B61208, CO1001, IMO-002 and TRITON significantly differed in SHT while Akwa-005, B70607, CO1001, Co504, EBON-006, IMO-002 and TRITON differed in TSW due to crops. Only CO1001 had significantly different values for all the vegetative traits across crops. Table 3 shows the effects of genotypes and crops were also significant ($P < 0.001$) for all the traits except for SHT and INL. The effect of crop was not significant for MLS, while genotypes × crops interaction was significant for GC, STD, MLS and TSW only. Variation in mean values for the traits of the genotypes was also presented in Table 3. Genotype B70607 was among those that had higher GC, TC, TSC, MLS and TSW while EBON-006 was prominent among those that had least values for the parameters. B61208, Cp65-357 and F141 were among genotypes with least TSW at harvest.

Table 3. Variation in vegetative performance of sugarcane genotypes evaluated in plant and ratoon crops in a Forest-Savannah-Transition agro-ecology across 2013 and 2014

Genotype	Germination count at 3 WAP	Tiller count at 12 WAP	Total stalk count at 54 WAP	Stalk height (m)	Stalk diameter (cm)	Internode length (cm)	Millable stalk (no.)	Total weight of stalk (kg/plot)
Akwa-005	63.67^{cd}	45.33^{cd}	62.92^{cd}	2.93^{ab}	2.70^{cd}	14.43^{a}	8.33^{e}	69.94^{ab}
B61208	24.67^{fg}	39.67^{d}	69.58^{cd}	5.67^{a}	2.62^{de}	12.27^{a}	10.^{67bc}	47.70^{cd}
B70607	152.83^{a}	86.00^{a}	95.83^{ab}	2.35^{b}	2.06^{f}	13.16^{a}	11.83^{ab}	71.69^{ab}
CO1001	99.67^{b}	64.50^{de}	82.92^{abc}	3.01^{ab}	2.47^{de}	16.50^{a}	11.50^{ab}	72.52^{ab}
Co504	34.83^{efg}	41.17^{d}	58.83^{cd}	2.65^{ab}	3.07^{ab}	11.65^{a}	10.17^{bcd}	66.33^{abc}
Cp65-357	51.83^{de}	29.00^{de}	48.92^{de}	1.88^{b}	2.39^{e}	11.61^{a}	8.67^{de}	35.99^{d}
DB 37/145	45.33^{de}	40.33^{d}	50.33^{cd}	2.69^{ab}	2.70^{bc}	13.38^{a}	8.00^{ef}	63.49^{abc}
EBON-006	16.17^{g}	17.50^{e}	29.67^{e}	2.35^{b}	2.87^{bc}	12.19^{a}	9.33^{cde}	60.39^{bc}
F141	99.17^{b}	45.67^{cd}	84.83^{abc}	2.33^{b}	2.05^{f}	28.25^{a}	12.68^{a}	50.48^{cd}
Hat-4	59.50^{d}	32.17^{de}	64.75^{cd}	2.46^{ab}	3.10^{a}	13.13^{a}	6.33^{f}	72.10^{ab}
IMO-002	68.50^{cd}	68.00^{ab}	98.50^{a}	2.99^{ab}	2.65^{cd}	14.40^{a}	9.00^{cde}	80.33^{ab}
TRITON	84.33^{bc}	45.67^{cd}	78.92^{abc}	2.97^{ab}	2.56^{de}	14.99^{a}	7.67^{ef}	75.98^{ab}
Statistics								
Mean	66.71	46.25	68.83	2.85	2.60	14.66	9.51	63.91
CV (%)	23.02	31.72	25.07	28.39	7.06	17.23	14.42	18.70
MS *genotype* (df=11)	8699.19***	2080.56***	2503.81***	5.42^{ns}	0.66***	122.59^{ns}	21.41***	1034.09***
MS *crop* (df=1)	112575.13***	16622.72***	14734.72***	17.02^{ns}	1.00***	463.80^{ns}	4.01^{ns}	12329.47***
MS *genotype ×crop* (df=11)	7397.94***	603.03^{ns}	554.02^{ns}	5.36^{ns}	0.18***	129.39^{ns}	13.56**	952.53***

Means with different alphabets among genotypes were significantly different.

MS, CV, LSD, ^{ns}, **, ***, are mean square, coefficient of variation, least significant different, not significant, significant at P<0.01 and 0.001, respectively.

Variation in flowering of the sugarcane genotypes

Significant variation (p<0.001) existed for all the flower traits between plant and ratoon crop (Table 4). There was also significant difference in the scores for flowering period (FP) but not for flowering intensity (FI) and flowering survey (FS) due to crops. Mean values for days to flowering initiation (DFI), days to flowering flagging (DFF), days to flowering tipping (DFT) and days to flowering arrow emergence (DFA) were higher in the plant crop than ratoon crop in all the genotypes except B61208, B70607 and TRITON. In plant crop, AKWA-005, DB37/145, EBON-006 and IMO-002 were among those that had the highest values for DFI, DFF, DFT and DFA. However, TRITON had the highest values for the flower traits in the ratoon crop. Values for the traits were least in B70607 in both plant and ratoon crops. It was found that Akwa-005, Co504 and IMO-002 had significantly similar vales for the traits in the two crops.

Pooled ANOVA of the flowering parameters showed that effects of genotypes, crops and genotypes × crops were significant (P<0.001) (Table 5). Mean DFI, DFF, DFT and DFA were 277.9, 304.2, 313.0 and 318.2 days, respectively. The scores for FP, FI and FS varied significantly between crops, and among genotypes within crops. Scores for FP, FI and FS ranged from 1.2 to 2.2 while CVs for the traits ranged from least (0.0%) to highest (25.5 %). Genotype B70607 had the highest DFI, DFF, DFT and DFA while Co504 and TRITON were conspicuous among those with least values for the traits. The B61028 and CO1001 were close to B70607 in their values for the traits while DB37/145 had values close to the Co504 and TRITON. Scores of FI ranged from 1.0 to 2.0 with over 60% of the genotypes having score 1.0 and about 60% also had FS scores of 1.5 which was the highest score for the trait across plant and the ratoon crop.

Table 4. Variation in flowering traits of sugarcane genotypes evaluated in plant and ratoon crops in a Forest-Savannah-Transition agro-ecology in 2013 and 2014

Genotype	Days to flower initiation		Days to flower flagging		Days to flower tipping		Days to flower arrow emergence		Flowering period (1-3)		Flower intensity (1-3)		Flower survey (1-3)	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
Akwa-005	299.0	242.0*	314.0	269.0*	321.0	279.0*	391.0	289.0*	2.0	2.0^{ns}	1.0	1.0^{ns}	1.0	1.0^{ns}
B61208	242.0	237.0*	253.5	249.0^{ns}	263.5	253.0^{ns}	270.0	261.0^{ns}	2.0	1.0*	1.0	1.0^{ns}	2.0	1.0*
B70607	228.0	227.0^{ns}	242.0	233.0^{ns}	254.5	244.7^{ns}	262.0	252.7^{ns}	1.0	1.0^{ns}	1.0	1.0^{ns}	2.0	1.0*
CO1001	275.5	248.0*	285.5	254.0*	290.5	263.0*	296.0	273.3*	1.0	2.0*	1.0	1.0^{ns}	2.0	1.0*
Co504	296.5	262.0*	312.5	276.7*	319.5	281.0*	330.0	291.7*	3.0	3.0^{ns}	1.0	1.0^{ns}	1.0	1.0^{ns}
Cp65-357	270.5	264.7^{ns}	284.5	278.0^{ns}	292.0	287.7^{ns}	304.0	298.7^{ns}	2.0	3.0*	1.0	1.0^{ns}	1.0	1.0^{ns}
DB 37/145	312.0	260.7*	323.5	274.0*	328.5	282.0*	330.0	288.7*	2.0	3.0*	2.0	2.0^{ns}	1.0	2.0^{ns}
EBON-006	312.5	254.0*	326.0	264.0*	335.0	274.0*	342.0	285.0*	2.5	3.0*	1.0	1.0^{ns}	1.0	2.0^{ns}
F141	264.0	237.0*	275.5	249.0*	284.5	251.7*	296.0	261.0*	2.0	1.0*	1.0	1.0^{ns}	1.0	1.0^{ns}
Hat-4	282.5	249.0*	293.5	265.0*	315.5	279.0*	323.0	305.0*	3.0	3.0^{ns}	1.0	1.5*	1.0	2.0^{ns}
IMO-002	309.5	238.0*	311.5	249.7*	319.5	254.0*	327.0	264.0*	2.0	2.0^{ns}	2.0	2.0^{ns}	1.0	1.0^{ns}
TRITON	287.5	272.0^{ns}	297.5	285.0^{ns}	302.0	293.0^{ns}	313.0	303.0^{ns}	2.0	3.0*	1.0	2.0*	1.0	2.0^{ns}
Statistics														
Mean	281.6	249.3*	293.3	262.2*	302.2	270.2^{ns}	315.3	281.1*	2.0	2.3*	1.2	1.3^{ns}	1.3	1.3^{ns}
CV (%)	30.0	45.4	29.3	47.5	28.7	32.4	27.7	31.1	7.1	0.2	0.0	11.0	0.0	0.0
LSD	11.8	2.8	17.0	3.0	20.9	1.5	22.3	1.5	0.2	0.0	0.0	0.3	0.0	0.0
Mean square	30191.6***	558.1***	7559.9***	709.3***	2394.9***	778.8***	203.7***	975.0***	1.15***	2.3***	0.5***	0.6***	0.6***	0.7***

CV, LSD, ^{ns}, *, *** are coefficient of variation, least significant different, not significant, significant at P<0.5 and 0.001, respectively.

Table 5. Variation in flowering traits of sugarcane genotypes evaluated in plant and ratoon crops in a Forest-Savannah-Transition agro-ecology across 2013 and 2014

Genotype	Days to flower initiation	Days to flower flagging	Days to flower tipping	Days to flower arrow emergence	Period of flowering	Flower intensity	Flower survey
Akwa-005	279.0^{d}	308.5^{c}	317.5^{c}	322.0^{cd}	2.0^{d}	1.0^{d}	1.0^{b}
B61208	248.5^{b}	280.3^{a}	288.3^{a}	291.0^{a}	1.5^{e}	1.0^{d}	1.5^{a}
B70607	241.0^{a}	274.5^{a}	283.1^{a}	291.3^{a}	1.0^{f}	1.0^{d}	1.5^{a}
CO1001	249.3^{b}	280.3^{a}	291.0^{a}	300.2^{b}	1.5^{e}	1.0^{d}	1.5^{a}
Co504	302.8^{f}	327.1^{e}	337.3^{e}	343.8^{e}	3.0^{a}	1.0^{d}	1.0^{b}
Cp65-357	277.6^{d}	305.3^{c}	337.8^{e}	320.8^{c}	2.5^{c}	1.0^{d}	1.0^{b}
DB 37/145	299.3^{ef}	330.3^{e}	316.3^{c}	342.3^{e}	2.5^{c}	2.0^{a}	1.5^{a}
EBON-006	290.1^{de}	308.5^{c}	316.0^{c}	320.5^{c}	2.8^{b}	1.0^{d}	1.5^{a}
F141	263.5^{c}	289.3^{b}	297.8^{ab}	304.0^{b}	1.5^{e}	1.0^{d}	1.0^{b}
Hat-4	295.8^{e}	315.8^{a}	325.3^{d}	330.5^{d}	3.0^{a}	1.3^{c}	1.5^{a}
IMO-002	281.8^{d}	302.6^{c}	309.8^{b}	314.0^{c}	2.0^{d}	2.0^{a}	1.0^{b}
TRITON	306.3^{f}	328.3^{e}	335.5^{e}	339.5^{e}	2.5^{c}	1.5^{b}	1.5^{a}
Statistics							
Mean	277.9	304.2	313.0	318.3	2.2	1.2	1.3
CV (%)	25.5	22.8	18.9	15.6	4.8	8.3	0.0
MS *genotype* (df=11)	17227.8***	4195.44***	8492.36***	877.48***	2.62***	0.92***	0.40***
MS *crop* (df=1)	1330.4***	67008.5***	0.50^{ns}	87780.50***	0.78***	0.29***	0.13***
MS *genotype ×crop* (df=11)	13522.0***	4073.79***	14681.36***	301.26***	0.78***	0.14***	0.94***

Means with different alphabets among genotypes were significantly different.

MS, CV, **, *** are mean square, coefficient of variation, significant at P<0.01 and 0.001, respectively.

Brix percent of the sugarcane genotypes in first crop and first ratoon crops

Variations in the BP of the sugarcane in each of the crops are shown in Table 6. The CVs ranged from 1.16 % at 40 WAP in ratoon crop to 5.97 % at 36 WAP plant crop. Mean BP significantly differed between crops at 36 and 52 WAP only, where the values were significantly higher in the plant crop than the ratoon crop. Variation existed in the BP among the genotypes within and across crops. At 36 WAP, nine out of the 12 genotypes differed in their brix values for each crop. Only genotypes B61208 from the nine had BP higher in ratoon than plant crop. Genotypes B61208, DB 37/145, EBON-006 and IMO-002 had higher BP in plant crop than ratoon at harvest while B70607 had higher BP in ratoon crop. The remaining genotypes were similar in BP at the two crops. Genotypes Cp65-357 was among those that had highest brix percentages across sampling periods.

In the combined ANOVA, the effects of genotypes and genotypes × crops were significant ($P<0.001$) for the BP at all the sample periods, but the effects of crops were significant ($P<0.001$) for the BP at 36 and 54 WAP only (Table 7). The CVs were less than 6.0% for all the parameters. Genotypes Cp65-357 consistently had highest BP across the sampling periods while B61208, Co504, EBON-006, F141 and IMO-002 were genotypes that consistently recorded the least BP at each of the sampling periods.

4.0 DISCUSSION

Significant differences in GC, TC_8, TC_{12} and TSC due to effects of genotypes and crops are indicative of the difference in genetic composition of the crop which is capable of affecting establishment and ability of the crop to regenerate after harvesting in one season. The significant difference also suggests variation in the response of each genotype to the weather and edaphic conditions during the growth of the crop. Sugarcane responds to the presence or absence of water during the growth (Rehm and Espig, 1991; Onwueme and Sinha, 2003).

Table 6. Brix percent (%) of sugarcane genotypes evaluated in plant and ratoon in a Forest-Savannah-Transition agro-ecology across 2013 and 2014

Genotype	36 WAP		40 WAP		44 WAP		Harvest	
	First	Ratoon	First	Ratoon	First	Ratoon	First	Ratoon
Akwa-005	17.82	17.80^{ns}	19.23	19.50^{ns}	19.70	21.10^{ns}	21.55	22.00^{ns}
B61208	16.22	17.30*	18.63	18.37^{ns}	19.80	19.67^{ns}	22.93	19.57*
B70607	20.94	19.20*	19.07	19.80^{ns}	20.12	19.20^{ns}	18.65	20.27*
CO1001	20.80	18.30*	19.40	19.73^{ns}	21.30	21.40^{ns}	21.73	21.60^{ns}
Co504	19.24	17.60*	18.70	13.50*	19.96	20.90^{ns}	21.07	20.40^{ns}
Cp65-357	22.72	22.30^{ns}	22.21	20.00*	21.62	21.20^{ns}	22.05	22.60^{ns}
DB 37/145	17.50	16.20*	19.67	19.13^{ns}	20.94	21.67^{ns}	21.97	20.17*
EBON-006	19.03	14.40*	18.80	17.60*	21.05	19.40*	21.33	18.00*
F141	16.48	18.63^{ns}	16.77	19.50*	18.58	18.60^{ns}	20.93	21.27^{ns}
Hat-4	20.23	19.40*	19.27	18.10*	20.89	21.90^{ns}	22.65	22.60^{ns}
IMO-002	18.48	16.90*	17.67	18.87*	21.06	19.73*	22.15	19.27*
TRITON	19.58	17.90*	18.10	19.87^{ns}	20.37	20.80^{ns}	21.77	22.67^{ns}
Statistics								
Mean	19.09	17.99*	18.96	19.08^{ns}	20.45	20.46^{ns}	21.48	20.86*
CV (%)	5.97	5.08	2.32	1.16	3.15	3.16	3.64	4.40
LSD	1.93	1.55	0.74	0.38	1.09	1.10	1.33	1.56
Mean square	11.10***	11.04***	5.15***	1.86***	2.20***	3.55***	3.49***	6.76***

CV, ^{ns}, **, ***, are coefficient of variation, not significant different, significant at P<0.01 and 0.001, respectively

Differences existed in the genotypic performance of the crop in spite of adequate moisture for growth of the crop. This could be buttressed by the similarity in performance of some of the genotypes especially B61208, DB37/145 and EBON-006 for GC due to crops.

This results agrees with the findings of Gomathi et al. (2013) that the differences in growth parameters between the plant and ratoon crops at the formative phase were lesser than that of growth and maturity phases. The fact that total plant stand is a function of number of tiller that survive may be responsible for the higher values for establishment and growth parameters in the ratoon crop than in the plant crop. The performance of the genotypes at the early stage was higher in the ratoon than the plant crop. However, ratoon crop produced more tillers than the plant crop in this study while Gomathi et al. (2013) reported 17.0% reduction

Table 7. Pooled brix percent of sugarcane genotypes evaluated in plant and ratoon in a Forest-Savannah-Transition agro-ecology

Genotype	Brix percent ((%)			
	36 WAP	40 WAP	44 WAP	Harvest
Akwa-005	17.81^{ef}	19.37^{bc}	20.40^{bc}	21.55^{abc}
B61208	16.76^{f}	18.50^{efg}	19.73^{c}	22.93^{bcd}
B70607	20.07^{b}	19.43^{b}	19.67^{c}	18.65^{e}
CO1001	19.55^{bcd}	19.57^{b}	21.35^{a}	21.73^{abc}
Co504	18.42^{de}	18.60^{def}	20.43^{bc}	21.07^{cd}
Cp65-357	22.51^{a}	22.10^{a}	21.41^{a}	22.05^{ab}
DB 37/145	16.85^{f}	19.40^{bc}	21.30^{a}	21.97^{cd}
EBON-006	16.72^{f}	18.20^{fg}	20.23^{bc}	21.33^{de}
F141	17.56^{ef}	18.13^{g}	18.59^{c}	20.93^{cd}
Hat-4	19.81^{bc}	18.68^{de}	21.39^{a}	22.65^{a}
IMO-002	17.69^{ef}	18.27^{efg}	20.40^{bc}	22.15^{de}
TRITON	18.74^{cde}	18.98^{cd}	20.58^{ab}	21.77^{ab}
Statistics				
Mean	18.54	19.02	20.46	21.17
CV (%)	5.56	1.83	3.16	4.02
LSD	1.17	0.17	0.30	1.04
MS *genotype* (df=11)	17.65***	4.19***	4.37***	6.27***
MS *crop* (df=1)	21.51***	0.26^{ns}	0.01^{ns}	6.81**
MS *genotype × crop* (df=11)	4.47***	2.82***	1.38**	3.98***

Means with different alphabets among genotypes were significantly different.

MS, CV, ***, **, are mean square, coefficient of variation, significant at P<0.001 and 0.01, respectively in tiller production in the first ratoon over plant crop. The variances in the findings may be due to the interplay of the genotypes, their ratoon-ability and the environments which were different in the two trials. Ratooning in sugarcane have also been observed to be the expression of interplay of a cultivar's ratoon-ability, environmental influence and extent of ratoon management (Tripathi et al., 1982; Gilbert et al., 2006; Gomathi et al., 2013).

Performance of a cultivar varies with changes in environmental condition while different genotypes perform differently in same environment due to effects of genotypes × environment. This was responsible for the variation in the most of the growth and yield parameters of the sugarcane genotypes studied. The SHT, STD and NND were statistically similar in the two crops suggesting consistency in the vegetative growth of the crop, though establishment and early growth parameters differed among species an in crops. The INL differed among the genotypes because it is a qualitative trait which is controlled by non-dominant genes. The MLS that was only about 20.5% and 13.8% of the TC_{12} and TSC, respectively shows that large percentages of the tillers were lost before harvest or did not have diameter wide enough to qualify for milling. A millable stalk is expected to have at least 2.0 cm diameter. Most of the total stalk harvested were not millable due to damages caused by pests or pathogens and lodging. Bhale (1994) had also reported up to 60% mortality of tillers and thus less millable canes at harvest.

Mean weight of stalk is a yield parameter and may be expected to differ widely between crops because it is controlled by additive genes. The yield of sugarcane of each genotype changed from one environment to another suggesting the effect of environment on sugarcane productivity. Besides, the changes in environmental conditions, yield traits are quantitatively inherited (Kang, 2002). Genotypes CO1001, IMO-002 and TRITON are most prone to weather elements because the effects of crops affected most of the vegetative parameters of the genotypes. Moreover, ratoon-ability might have played significant roles in the poor performances of the three genotypes because of the effects of weather due to crops. Except in NND and SHT, the genotypes seemed to be consistent in their performance in the first crop because of the lower CVs in plant crop than ratoon. Interactive effects of the genotypes with weather might be responsible for the high CV for the SHT which is itself a function of NND. The genotypes × crops had significant effects on GC, TC_8, TC_{12}, MLS and TSW. Hence, prediction of performance of the genotypes based on these traits may be difficult.

The B70607, IMO-002 and Hat-4 had high values for multiple traits in the two crops while only CO1001 had significantly different values for all the vegetative traits across crops. Therefore, B70607, IMO-002 and Hat-4 may be identified as most promising in plant and ratoon crops while CO1001 may be identified as most promising for ratooning. The CO1001 may be further evaluated for its ability for high productivity in more than one ratoon crops. Mean values for DFI, DFF, DFT and DFA which were flowering traits were higher in the plant crop than in ratoon crop. This suggests that the crop flowers earlier in the plant crop than the ratoon. However, there are exceptions to this as B61208, B70607 and TRITON were not influenced crop (plant or ratoon crop). Genotypes that had higher flower efficiency, for instance DB 37/145, Hat-4, IMO-002 and TRITON, are identified for breeding purposes. Effects of genotypes, crops and genotypes × crops were significant for most of the flower traits showing variation in the response of the genotypes to weather condition.

The CVs for BP parameters were low and similar since of the effect of weather was negligible on the trait. This also shows uniformity in the management of the experiment, therefore variation in BP in the study was due to factor effects (genotypes and crops). Mean BP significantly differed between planting crops for brix at 36 WAP and harvest brix only because these were the critical periods for change in quality of the parameter. Muchow et al. (1993); Gilbert et al. (2006) found that the peak sucrose content of sugarcane at harvest time is affected by different growing and plant physiological conditions during the maturation period. In the same vein, Das et al. (1996); Shikanda et al. (2017) had shown that BP significantly correlated with height of sugarcane. The height of the cane was found to be significantly different, especially at early growth stage. This is also responsible for nine (75 %) of 12 genotypes differing in their BP for each crop at 36 WAP. Only one genotype (B61208) from the nine had BP higher in ratoon crop than the plant crop. Genotype Cp65-357 was among those that had highest BP across sampling periods, thus it can be identified as promising. The BP values were significantly higher in the plant crop meaning that plant crop supports higher sucrose production than the ratoon crop. Genetic factor could have also played significant roles, since different genotypes had different BP within and across crops. According to Calderon (1996), genotypes B70607, Cp65-357, Hat-4 and CO1001 that had highest BP at 36 WAP can be classified as early maturing, Co504 and TRITON were medium maturing while Akwa-005, B61208, IMO-002, DB37/145, EBON-006 and F141 are late maturing. The author had classified sugarcane genotypes that have relatively high sucrose content in early stage early maturing and vice versa.

CONCLUSION

Genotypes B70607, IMO-002 and Hat-4 are most promising in both plant and ratoon crops. Genetic factor played significant roles in the crop's sucrose production. Genotypes DB37/145, Hat-4, IMO-002 and TRITON are identified as promising for breeding purposes. Genotypes Cp65-357 and CO1001 may be evaluated for ratoon-ability in more than one ratoon cropping for high sucrose percentages.

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