Original Research Article

Breeding potential and multivariate analyses of morphological and yield traits in industrial sugarcane(*Saccharum officinarum*L.) accessions in a humid tropical agroecology

ABSTRACT

Sugarcane (*Saccharum officinarum* L.) is propagated mostly by vegetative method. Although vegetative propagation conservesplant's germplasm; it poseschallenges in crop breeding. This field study assessed the breeding potentialof twelve industrial sugarcane accessions in a humid tropical agroecology of Nigeria. The experimentwas laid-out in a randomised complete block design with three replications. Accessions AKWA-005, B70607, C01001, CP65-357, DB37/45 and F141 produced flowers; an indicative trait of their suitabilityas prospective materials for hybridization.AccessionDB37/45 had the highest brix valueof 16.3%, followed by B61208with 15.7%, accession C01001 had the highest cane yield (58.9 t/ha) and longest stalks (150 cm); these further highlighted the potentialsof C01001, DB37/45, CP65-357, B61208 and AKWA-005 for yieldimprovement in sugarcane through selection. Whereas principal component and hierarchicalcluster analyses (Ward's method) grouped HAT4, F141 and IMO-002 together, the other accessions formed a separate but distinct grouping. These groupings provided a background information as an aid to selection of similar accessions. Cluster analysis and linear correlation identified significant (P =.05) positive association between the following traits: stalk girth, stalk length and cane yield. Thus, these traits can be simultaneously selected for andimproved in sugarcane. Overall, accession C01001, DB37/45, CP65-357, B61208 and AKWA-005 are recommended for inclusion in the breeding for adaptable linesof sugarcane in the humid tropical agroecology.

Keywords: *Saccharum officinarum*L.; tropical agroecology; multivariate analysis; crop breeding; Brix

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INTRODUCTION

Sugarcane (*Saccharum officinarum*L.) has many domestic and industrial uses because the stem is rich in sugar, mainly sucrose. Sucroseis the table sugar consumed by most people all over the world.It isan ingredient inthe making of many medicinesand beverages;it is also used assweetener in confectionery and related industries. It is the energy source of the ethanol used as fuel by 80% of the eco-friendly cars in Brazil; about 5.4 billion gallons of fuel was produced from sugarcane in 2006 [1]. Chopped and dried sugarcane stalks are used as cattle feed.Sugarcaneis a perennial plant in the family Poaceae (grass family); ithas jointedfibrous stalksand can grow up to six metres inheight. It is cultivatedmostly byvegetative method; ensuring that the genotypes are conserved forgenerations. However, the demerit of the vegetative propagation isthe non-exploitation ofsegregation and recombinationofgenesassociated with sexual reproduction, which are crucial forthe uncovering of possibleinherent geneticvariability in the species.

Sexual reproduction produces new gene combinations leading to the variation in the genotypes and phenotypes of the progeny; in contrast, in most asexual reproduction processes, the progeniesare identical to their parents. Other demerits of vegetative reproduction in some species include non-flowering, reduced flowering and poor seed set, which hinder their breeding potential. Also, due to the associated genetic uniformity of vegetatively propagated crops, pests and diseases attack could be very devastating.

The genotype, environment and the interaction between genotype and environment have separate and combined roles to play in determining the phenotypic value of a plant. Since vegetativelypropagated crops areoften highly geneticallyalike; any variation withinthelines is mostly induced by environmental effect.This could make intra-varietal selectionineffective unless there wasgermplasm contamination that resulted from mechanical mixture of lines and/or mislabelling of the varieties. However, inter-varietal selection in vegetatively propagated species would be effective,in that,a single plant selected from a population can form the basis for developing a new variety; and either one or two cycles of selection are enough to produce a fixedgenotype.Alternative methods of breeding vegetatively propagated orclonal cropsare through mutation breeding technique. Iwo *et al*. [2]reported success in the improvement in rhizome yield and oleoresin contentin ginger and Kaur *et al*. [3]have increased cane yield and red rot resistance in sugarcanethroughgamma ray radiation. In another breeding effort in sugarcane,Usman [4]developed disease-free plantlets through tissue culture technique.

Sugarcane is grown in most tropical countries [5].The total world production was about 1.7 million MT,on land area of 23.8 million hectares; of which Brazil produced more than 300,000 MT; India 285, 000 MT and China 114, 000 MT,in 2009 [6]. Nigeria is one of the sugarcane producers in Africa; the crop is produced for domesticsugar used although the sugar is grossly inadequate,the country augments by import of over $500 million worth of brown sugar from Brazil annually [7], this situation can be remedied.

Generally, agricultural productivity has fallen greatly in Nigeria, the countryproduces only about 5% of world palm oil and groundnut [8], against 50% and 30% respectively in the 1960s; this trend has affected the production of other crops, including sugarcane. Development in the sugar industry has been very slow due to over-dependency on sugar importation, in spite of the availability of land, manpower and other resources for sugarcane production [9].Wada *et al*. [10]noted several factors that hindersugarcane production in Nigeria and North Africa. The factors areinsufficient investment, low capital outlay, lack of good market network and spacefor agricultural land, biotic factors (e.g. cane beetles (*Migdolusfryanus*) andsoft scale insect (*Pulvinariaternivalucta*(Newstead)and several abiotic stress factors. Whereas, the economic and political concerns identified in sugarcane production can be amended through appropriate policies, thebiotic and abiotic factors are issues that should trigger sugarcane breeding efforts.

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The goals of sugarcane breeding programmes can be to increase sugar yield, plant biomass(height, plant girth and number off stalks per plot)andresistance to pests and diseases.There is need to identify the most suitable genotypes for cultivation in each of the agroecologies of Nigeria. Developing exotic cultivar of industrial sugarcane with high sugar yield for the humid tropical agroecology of Nigeria is very necessary. The more widely adaptable the cultivar, the more productive the venture will be.In varietal trials, the breederfinds the most adaptable variety basedon somedesirabletraits. Multivariate analysis tools, such as principal component, factor and cluster analyses, discrimination and classification can be applied to study multiple characters simultaneously [11, 12, 13].

Selection for yield potential is useful for the improvement of crops and it is usually the main objective of breeding programmes [13]. Varietal development is a continuous process that involves evaluation for high yield, better quality, responseto fertilizer, resistance to diseasesand other pests and tolerance to abiotic stress dependingon the objective of the breeding programme.

The objective of this study was to evaluate twelve accessions of industrial sugarcane for morphological and yieldtraits in a humid tropical ecology for breeding purpose.

Materials and methods

Twelve industrial sugarcane accessions; namelyAKWA-005, B61208, B70607, C01001, C0504, CP65-357, DB37/45, EBON-006, F141, HAT4, IMO-002 and TRITON,wereobtained from the National Cereals Research Institute (NCRI), Badeggi, Niger State, Nigeria. The accessionswere grownin the field trials in the 2014 and 2015 cropping seasons in the Teaching and Research Farm of the Faculty of Agriculture, Forestry and Wildlife Resources Management, University of Calabar, Nigeria. Calabar (Latitude 4.5 ^{o}N; Longitude 8.0 ^{o}E) is a rain-fedregion of Nigeria; the average rainfall ranges from 2000 to 3500 mm. Mean daily temperature is from 27 to 35 ^{o}Cwith the relative humidity rangingfrom 70 to 85% annually. The area has rainfall, almostall year round, with an exceptionof a 10 to 15days dry spellwithin the first and second weeks inAugust. Rainfall markedlyintensifies soil erosion and coastal flooding in this area [14]. The weather, vegetationand the other conditions qualify Calabar as a humid tropical ecology. The physico-chemical composition of the soil in the experimental site is presented in Table 1.

Table 1. Some physical and chemical soil properties of the experimental site (0 – 30cm)

Physico-chemical Parameter
Physicalproperties
Clay = 10.2%
Silt = 38.6%
Sand = 50.3%
Texture = Sandy loam
Porosity = 57.2%
Chemicalproperties
pH (H_2O) = 6.0
Organic Carbon = 8.0 gkg^{-1}
Available P= 5.5 mgkg^{-1}
Total N = 0.6 gkg^{-1}
Exchangeablebases
Ca = 0.9 Cmolkg^{-1}
Mg = 0.6 Cmolkg^{-1}
K = 0.1 Cmolkg^{-1}
Na = 0.4 Cmolkg^{-1}
CEC = 4.0 Cmolkg^{-1}

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The sugarcane accessions were planted in the field in a randomized complete block design (RCBD) in three replicates. The main plot was 23 m x 44 m, each plot was 5m x 1.5m, between row spacing was 1.5m and within row spacing was 1m. The same-aged cane cuttings for planting had three nodes. Standard agronomic practices for sugarcane cultivation were carried out.Data collected were on sproutingpercentage (SPR%) at 21 days after planting (DAP) and establishment percentage (EST%) atfive months after planting (MAP). Flowering behaviour (FLBEH), scored as flowering = 1 and non-flowering = 0; flowering cycle (FCY) were set as Early flowering =139-168 DAP, Medium flowering =169-200 DAP and Late flowering =201-245 DAP; flowering intensity was scoredas shy = 0, medium = 1andprofused =2; and Sexuality (SEX) was in three categories; no-flower(NF), staminate (Male)andpistillate (Female)plants. Yield traits were brix value (^{o}Bx) measured with hand held refractometer at 12 MAP, stalk length (SLNG), stalk girth (SGTH) and number of millable stalks per plot (MLST).Cane yield (YIELD) was the weight of millable stalks in tonnes per hectare (t/ha).Heritability in broad sense was estimated according to Hasan *et al*. [15]. Genetic advance was calculated according to the formula given by Johnson *et al*. [16].

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Analysis of variance (ANOVA) of the morphological characteristics was computed with the GenStat 8.1 package [17], significant differences between means were compared using Duncan's New Multiple Range Test (DNMRT) at 95% confidence level. The multivariate analyses were computed with Past 3 package (Hammer *et al*. [18]; principal components with Eigen values greater than one are discussed [19]. Pearson's (linear) correlation coefficients were also calculated.

Results and Discussion

Some morphological characteristics in the 12 industrial sugarcane accessions are presented in Table 2. Thesprouting percentage ranged from 50 to 100 %,all the cane-setts plantedofC01001 and DB37/45sprouted in the humid tropical agroecology.

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The establishment percentage in the sugarcane accessions followed the pattern in the sprouting; at five months after planting, all the stands (100%) of DB37/45 were still growing. AKWA-005, B70607, C01001, CP65-357, DB37/45 and F141 produced flowers within168 days after planting (DAP). AKWA-005, C01001 and DB37/45 were declared as early flowering accessions. B70607 and CP65-357 were medium flowering accessions and F141 was a late but profusely flowering accession with an intensity of 2, followed by AKWA-005 with an averageflowering intensity of 1.5;C01001, CP65-357 and DB37/45 had an intensity of 1.33, while B70607 hadan intensity of 1. Flowering behaviour, flowering cycle and intensity are very important attributes of plant breeding; they determine planting time, ease and suitability for crossing of either individual or a group of plants. The flowering intensity determines the nature of the sexuality in plants. Sugarcane accessions (C01001 and CP65-357) which were considered 'shy'in the flowering intensity shed pollen very poorly. These accessions could be exploitedas female plantsduring hybridization,thus eliminating the need for artificial emasculation. The accessions, AKWA-005, B70607, C01001, CP65-357, DB37/45 and F141, produced flowers in this study andare suitable accessions for hybridization.

The Brix values (^{o}Bx) ranged from 11.7 % (EBON-006) to 16.3% (DB37/45). The Brix values in this experiment are comparable to the sucrose content in somevegetables, such as watermelon and pineapple[20]. The stem girth ranged from 5.5 cm(F141)to 8.2 cm(DB37/45).The stem girth for DB37/45 and B61208 were not significantly different (*P* = .05). The stalk length of 150.3 cm in C01001 was the longest, but was not significantly (p≥0.05)longer than the 140.3 cm in AKWA-005 (Table 3). The number of millable stalks per stool ranged from 3.8 (HAT4)to 8.3 (CP65-357). The meannumber of millable stalks was 6.3; six accessions (B70607, C01001, CP65-357, EBON-006, F141 and IMO-002) produced more millable stalksthan the group's average (Table 3). The cane yield ranged from 9.4 t/ha(HAT4) to 58.9 t/ha(C01001). The average cane yield was 33.85 t/ha;five accessions; AKWA-005, B70607, C01001, CP65-357 and EBON-006produced higher cane yield than the average.C01001 produced significantly(*P* = .05)the highestcane yield (58.9 t/ha) than all the other accessions, EBON-006 followed (46.2 t/ha) (Table 3).

Table 4 presents the genetic parameters of the morphological and yield traits of the industrial sugarcane accessions. The broad sense heritability was generally low for stem length (24%) and cane yield (18.2%); moderate for the sprouting percentage (63%), establishment percentage (58%), Brix value (50%), number of millable stalks per stool (41%), and stalk girth (43%).Since sugarcane is mostly cultivated vegetatively via its clones,heritabilityis literally fixed and would have minimal importance, with an exceptionto flowering clones which can bepropagated via their seeds. Zhao *et al*. [21], Nwosu *et al*. [22]and Idahosa *et al*. [23] established that the magnitude of thephenotypic coefficient of variability(PCV) and heritabilityare affected by the environment,

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Comment [XXXX12]: Is outside the journal's norms the effect is evident on the phenotype. High PCV and heritability values implylow interference of the environment on the trait under consideration andvice versa. In this study, heritability of cane yield was low, suggesting that environmental factors highly influence the trait, and mass selection as a breeding method would be very slow as far as breeding for cane yield is concern.

‘ The principal component and Eigen values of the industrial sugarcane accessions in the humid agroecology are presented on Table 5. Six of the principal components (PC) had Eigen values greater than 1.0; these were PC1 to PC6. The PC1loaded 82.6%of the variations among the morphological and yield traits on the sprouting (%), establishment (%)and stalk length. The PC2 loaded 10.8% of the variationon the stalk length and stalk yield per hectare.

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Table 2. Some morphological traits of the industrial sugarcane accessions grown in the humid tropical agroecology.

Variety	SPR%	EST%	FLBEH	FCY	FLINT	SEX
AKWA-005	88.9^{a}	88.9^{a}	1	Early	1.5	Male
B61208	94.4^{a}	94.5^{a}	0	NF	0	NF
B70607	83.3^{a}	86.1^{ab}	1	Medium	1	Male
C01001	100.0^{a}	94.4^{a}	1	Early	1.33	Fem
C0504	91.7^{a}	86.1^{ab}	0	NF	0	NF
CP65-357	88.9^{a}	88.9^{a}	1	Medium	1.33	Fem
DB37/45	100.0^{a}	100.0^{a}	1	Early	1.33	Male
EBON-006	88.9^{a}	88.9^{a}	0	NF	0	NF
F141	63.9^{b}	66.7^{bc}	1	Late	2	Male
HAT4	50.0^{c}	50.0^{d}	0	NF	0	NF
IMO-002	61.1^{b}	61.1^{c}	0	NF	0	NF
TRITON	91.7^{a}	91.7^{a}	0	NF	0	NF

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Key: [a]Means with the same letter under the same heading are not significantly different at 5% probability level of DNMRT;SPR% = sproutingpercentage;EST% = percentage of the plants growing per plot;FLBEH = Flowering behaviour; FCY=Flowering cycle; FLINT = Flowering intensity SEX = Sexuality; NF = Non-flowering; fem = female.

Table 3. Some yield traits of the industrial sugarcane accessions grown in the humid tropical agroecology.

Variety	ºBx	SGTH	SLNG	MLST	YIELD
AKWA-005	11.8^{e}	7.1^{bc}	140.3^{ab}	6.1^{c}	36.2^{bc}
B61208	15.7^{ab}	8.1^{a}	130.8^{b}	4.8^{e}	33.5^{bc}
B70607	13.1^{cd}	5.6^{d}	139.1^{b}	7.7^{b}	35.1^{bc}
C01001	13.8^{c}	7.1^{bc}	150.3^{a}	7.3^{b}	58.9^{a}
C0504	13.3^{cd}	7.4^{b}	117.6^{c}	5.6^{d}	24.4^{c}
CP65-357	14.8^{b}	6.3^{cd}	131.0^{b}	8.3^{a}	42.1^{b}

DB37/45	16.3^{a}	8.2^{a}	126.7^{bc}	5.7^{d}	35.6^{bc}
EBON-006	11.7^{e}	6.7^{cd}	130.6^{b}	6.5^{bc}	46.2^{b}
F141	12.3^{de}	5.5^{d}	114.8^{cd}	6.7^{bc}	28.6^{c}
HAT4	13.4^{cd}	6.1^{cd}	98.6^{d}	3.8^{f}	9.4^{d}
IMO-002	12.5^{d}	6.0^{cd}	111.3^{cd}	7.1^{b}	27.2^{c}
TRITON	14.7^{b}	7.7^{b}	130.2^{b}	6.1^{c}	29.0^{c}

Key:[a]Means with the same letter under the same heading are not significantly different at 5% probability level of DNMRT; °Bx = brix value (%);SGTH = Stalk girth (cm);SLNG = Stalk length (cm);MLST = number of millable stalk per stool; YIELD = Cane yield (t/Ha).

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Beheshtizadeh*et al.*[24] and Rymuza*et al*. [12] used principal component analysis to show that spike yield, tillering, seed weight and seed yield were important traits in the breeding of wheat (*Triticum a*esti*vum*). Maji and Shaibu [13] showed similar relationships in some rice genotypes; they demonstrated thattillering, seed weight and seed yield were important traits for selection breeding. In this study, the clonal reproductive attribute in sugarcane propagation must be considered in the choice of the method of breeding the crop. Although wheat,rice and sugarcane are in the family Poaceae; wheat and rice are seed propagated, while sugarcane is mainly cultivated by stem cuttings; stalk characteristicsare valuable traits to befocused oninsugarcane breeding. In the scatter plot of the principal component analysis (Figure 1), HAT4, IMO-002, CO504 and F141 were captured in the left axis (quadrant II and III) of the ellipsis, while the following accessions; AKWA-005, B61208, B70607, C01001, CP65-357, DB37/45, EBON-006 and TRITON, were captured on the right axis (quadrant I and IV), the later accessions demonstrated association with useful traits, such as, stalk length, stalk girth and number of millable stalks. The accessions on the right axis are the materials to be used for the improvement of the yield traits in this population.

Figure 2 shows the clustering similarity between the genotypes and the magnitude of deviation among the 12 industrial sugarcane accessions in the study. These accessions were partitioned into two major clusters, HAT4, F141 and IMO-002 were in the first cluster and C01001, B70607, AKWA-5, C0504, DB37145, B61208, TRITON, CP65-357 AND EBON-006 in the second cluster.Accessions C01001, B70607 and AKWA-5 were in a sub-cluster of the second cluster. The accessions in the same cluster (more so in sub-cluster) share closer genetic association than accessions in different and distanced clusters. Fawaz *et al*. [25] found phylogenetic diversity and similarity in sugarcane genotypes in a study of genetic variation.The cluster analysis has confirmed the observation in scatter plot of the principal component analysis (Figure 1); that is,HAT4, F141 and IMO-002 on one hand were morphologically different from the other accessions.

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Table 4. Genetic parameters of selected morphological and yield traits of industrial sugarcane accessions in humid tropical agroecology

Trait	Mean	σ^2_g	σ^2_e	σ^2_p	GCV	PCV	H^2_B	GA	GAM
SPR%	83.6	219.9	129.2	349.1	17.7	22.3	63	24.25	29.02
EST%	83.1	189.8	135.6	325.3	16.6	21.7	58	21.55	25.93
°Bx	13.6	1.8	1.8	3.6	10.3	14.6	50	1.95	14.37
SGTH	6.8	0.6	0.8	1.4	11.4	17.4	43	1.05	15.38
SLNG	126.8	-276.9	1433	1156.2	13.1	26.3	24	16.81	13.26
MLST	6.3	1.1	1.5	2.6	16.3	25.5	41	1.36	21.57
YIELD	33.9	59.7	268.5	328.2	22.8	53.5	18.2	6.79	20.06

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Key: σ^2_g = Genetic variance; σ^2_e = Environmental variance; σ^2_p = Phenotypic variance; GCV= Genotypic coefficient of variability; PCV = Phenotypic coefficient of variability; GA = Genetic advance; H^2_B = Heritability in the broad sense (%); GAM = Genetic advance as percentage of the mean;SPR % = sprouting percentage; EST % = percentage of the plants growing per plot; °Bx = brix value (%); SGTH = Stalk girth (cm); SLNG = Stalk length (cm); MLST = number of millable stalk per stool; YIELD = Cane yield (t/Ha)

Table 5. Principal componentandEigenvalues of the industrial sugarcane accessions in humid tropical agroecology

ACCESSION	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8
SPR%	0.60	0.05	0.42	-0.66	-0.03	0.17	0.04	-0.05
EST%	0.57	0.09	0.36	0.70	-0.09	-0.20	-0.05	0.01
FLBEH	0.01	0.03	-0.02	0.07	-0.03	0.18	0.48	-0.12
FLINT	0.00	0.05	-0.01	0.11	-0.08	0.22	0.81	0.14
BRIX	0.02	-0.02	0.11	0.19	0.78	0.58	-0.12	-0.08
SGTH	0.02	-0.02	0.07	-0.08	0.28	-0.20	0.04	0.91
SLNG	0.47	0.43	-0.76	-0.04	0.13	-0.03	-0.03	0.01
MLST	0.01	0.04	-0.08	0.12	-0.54	0.69	-0.29	0.34
YIELD	-0.32	0.89	0.31	-0.02	0.00	-0.02	-0.04	0.00
Eigen value	**705.18**	**91.93**	**50.44**	**3.04**	**1.36**	**1.05**	**0.36**	**0.068**
% variance	**82.62**	**10.77**	**5.91**	**0.33**	**0.16**	**0.12**	**0.1**	**0**

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Key: SPR % = sproutingpercentage;EST % = percentage of the plants growing per plot;FLBEH = Flowering behaviour; FCY=Flowering cycle; FLINT = Flowering intensity, SEX = Sexuality; NF = Non-flowering; fem = female; °Bx = brix value (%); SGTH = Stalk girth (cm); SLNG = Stalk length (cm); MLST = number of millable stalk per stool; YIELD = Cane yield (t/Ha)

The growth and yield traits were also subjected to Single linkage clustering analysis, the stalk length, establishment and establishmentper cent were in a cluster different from yield, flowering behaviour, flowering intensity, brix value and stalk girth (Figure 3). Variatesin the same cluster are closer and can be improved simultaneously in a breeding programme.

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The linear correlation matrix of some growth and yield traits are presented on Table 6. The cane yield per hectare had significant positive and high correlation (r= 0.80, P = .05) with the number of millable stalks per stool and positive but moderate correlation (r= 0.47, P = .05) with the stalk length and the stalk girth (r = 0.52, P = .05). Also, the stalk girth had positive but moderate correlation (r= 0.41, P = .05) with the number of millable stalks per stool. The brix value also had positive correlation (r= 0.62, P = .05) with the stalk girth but very low negative correlation (r= -0.18, P = .05) with the number of the millable stalks per stool. The trend in correlation between traits compares with the linear linkage clustering in this study. Traits that have significant positive correlation can be improved simultaneously in a breeding programme [23]; the traits include stalk yield, stalk girth and the stalk length. The brix per cent measures concentration of sugar, therefore had little or no relevance with traits evaluated in weight.

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Summary and Conclusion

Sugarcane is mainly grown by vegetative method; vegetative propagation poses challenges on sugarcane improvement and the breeding methods available are limited due to this propagation method. For example, selection can only be applied among varieties and in cases where there was mixture of the germplasm, this is because vegetative propagation does not have variability within a genotype. Breeding methods that require hybridization have their limitations because most clonal genotypes may not flower at all. In this study, six sugarcane accessions, AKWA-005, B70607, C01001, CP65-357, DB37/45 and F141out of the twelve accessions produced flowers, this means that the six accessions can be crossed, and backcross selection method is recommended for quick improvement of the yield traits through the classical plant breeding approach. AKWA-005, C01001 and DB37/45 flowered early, B70607 and CP65-357 were medium floweringand F141 was late flowering. This function is necessary to time planting and hybridization.

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The broad sense heritability values of stem length and cane yield were low,and those of sprouting and establishment per cent, brix value, number of millable stalks and stalk girth were moderate. If clonal selection is the method of choice in the breeding of these accessions, then heritability would not be important because the genetic make-up of progeny of vegetatively propagated plants do not change from that of their parents.In respect of the multivariate analyses, most of the variations in the growth and yield traits were due to heterogeneity in the traits, such assprouting and establishment per cent and stalk length.

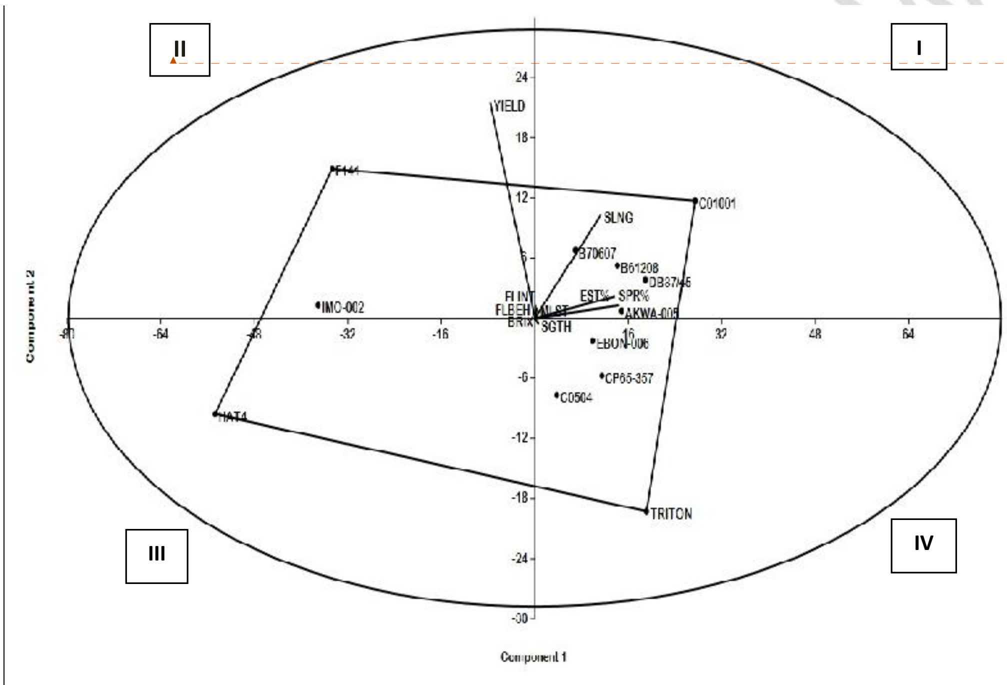

Figure 1. Diagram showing scatter plot of the PCA with 95% ellipsisof the industrial sugarcane accessions in humid agroecology.

KEY: SPR % = sprouting percentage;EST % = percentage of the plants growing per plot; FLBEH = Flowering behaviour; FCY=Flowering cycle; FLINT = Flowering intensity, SEX = Sexuality; NF = Non-flowering; fem = female; °Bx = brix value (%); SGTH = Stalk girth (cm); SLNG = Stalk length (cm); MLST = number of millable stalk per stool; YIELD = Cane yield (t/Ha)

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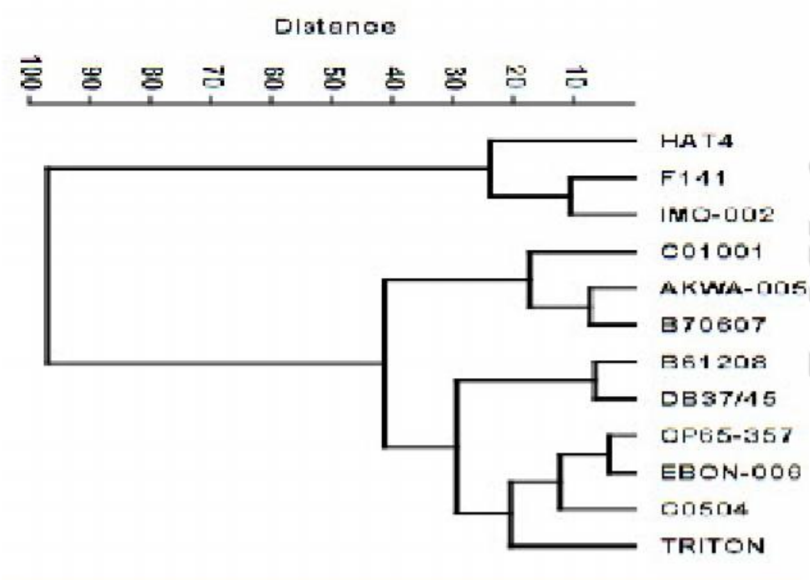

Figure 2. Dendrogram showing Ward's algorithm clustering of the industrial sugarcane accessions in humid tropical agroecology.

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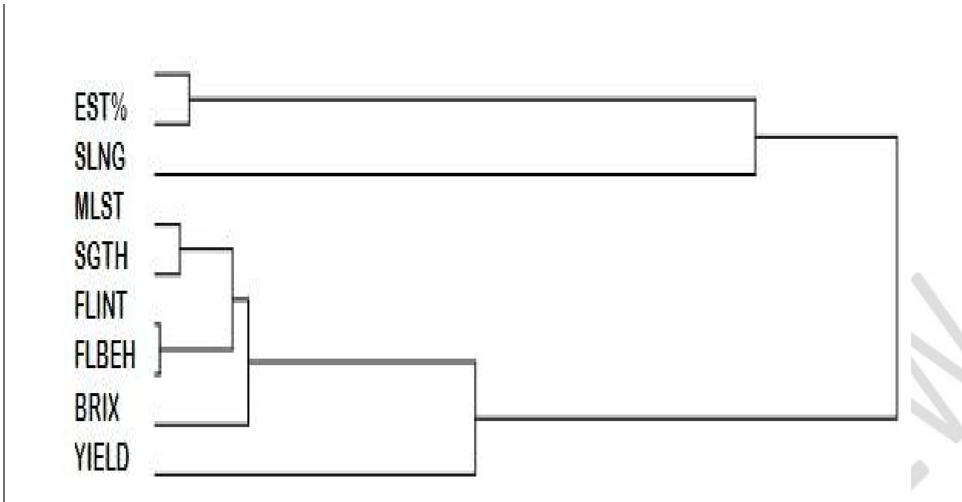

Figure 3. Dendrogram showing the relationship between the traits of the industrial sugarcane in the humid tropical agroecology. : SPR % = sprouting percentage;EST % = percentage of the plants growing per plot; FLBEH = Flowering behaviour; FCY=Flowering cycle; FLINT = Flowering intensity, SEX = Sexuality; NF = Non-flowering; fem = female; °Bx = brix value (%); SGTH = Stalk girth (cm); SLNG = Stalk length (cm); MLST = number of millable stalk per stool; YIELD = Cane yield (t/Ha)

Comment [XXXX29]: Move the figure to line 221

Table 6. Correlation matrix showing the association between the morphological traits in theindustrial sugarcane accessions

Comment [XXXX30]: Move the table to line 231

	EST %	FLBEH	FLINT	BRIX	SGTH	SLNG	MLST	YIELD
SPR%	0.988*	0.253	0.140	0.455	0.727	0.800*	0.223	-0.620
EST %		0.300*	0.185	0.465	0.69	0.814	0.253	-0.606
FLBEH			0.958*	0.057	-0.204	0.510	0.554*	0.165*
FLINT				-0.027	-0.235	0.378*	0.477*	0.296
BRIX					0.623*	0.112	-0.179*	-0.264*
SGTH						0.309	0.411*	0.523*
SLNG							0.510*	0.470*
MLST								0.801*

Key: SPR % = sprouting percentage; EST % = percentage of the plants growing per plot; FLBEH = Flowering behaviour; FCY=Flowering cycle; FLINT = Flowering intensity, BRIX = brix value (%); SGTH = Stalk girth (cm); SLNG = Stalk length (cm); MLST = number of millable stalk per stool; YIELD = Cane yield (t/hHa)

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Comment [XXXX31]: puts the conclusion, as presented in the summary

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