Research Article

Assessment of Variation in Newly Developed Sugarcane Genotypes for Morphological and Quality Associated Parameters

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Abstract | Sugarcane is a main cash crop of Pakistan grown extensively in varying agro-climatic conditions. It confers a sound economic base to the sugar industry and also supports paper and chipboard manufacturing industry. The rapid human population growth in the country has increased the sugar demand. The present position of low yield and recovery in sugarcane stipulates the breeders to take realistic innovative attempts in varietal development programs to evaluate and release new sugarcane of high cane and sugar yield potential to fulfill the sugar demand in the country. Limited work regarding appraisal of variation in lately evolved sugarcane genotypes for morphological and quality-related characters has been reported in Pakistan. Evaluation of sugarcane genotypes for desired attributes acceptable to growers and sugar mills is necessary before releasing them as commercial varieties. The study was undertaken to evaluate variations in sugarcane genotypes employing four morphological (Cane thickness, cane height, millable stalks, and cane yield) and four quality-related (Brix, pol, purity, and commercial cane sugar percentage) traits. Experiments were conducted in plant crop for two consecutive years 2018-19 and 2019-20 during the autumn cropping season at Makli farm of PARC-National Sugar and Tropical Horticulture Research Institute (NSTHRI), Thatta, Pakistan. A total of four sugarcane genotypes i.e., YtTh-1701, YtTh-1705, YtTh-1707, and YtTh-1730 against standard variety Thatta-10 as check were tested. The genotypes were developed from the exotic fuzz of China. The trials were conducted under RCBD with three replications. The ANOVA exhibited significant ($p \leq 0.05$) differences among the genotypes for cane thickness, cane height, number of millable canes, and cane yield, whereas, non-significant ($p \geq 0.05$) variations were observed for brix%, pol%, purity% and commercial cane sugar percentage (CCS%). The mean data showed a maximum cane yield of 150.84 t ha-1 for YtTh-1705, followed by YtTh-1707 (145.42 t ha^{-1}) and YtTh-1701 (142.29 t ha^{-1}). Whereas, the minimum yield of 104 t ha^{-1} was recorded in YtTh-1730 against the check variety (137.09 t ha^{-1}). Similarly, the maximum CCS of 12.08% was displayed by YtTh-1705, followed by check variety Thatta-10 with CCS of 11.73%. Whereas, the CCS% in other sugarcane genotypes was low as compared to check variety. Among the inspected sugarcane genotypes YtTh-1705 was found promising due to highly improved performance for quantitative and qualitative parameters. Therefore, can be included in the gene pool for further varietal development studies.

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Introduction

Sugarcane (*Saccharum officinarum* L.) is a highly valuable crop, being cultivated in tropical and subtropical climatic regions of the world on the whole for sugar production (Ochami and Ochieng, 2020). Its wider adaptability to varying climatic conditions offers a steady economic base for the survival of the sugarcane industry as the world's population is increasing rapidly and creating the necessity for food and renewable energy supply (Skocaj *et al*., 2013). Sugarcane is the fount of basic material for the sugar industry to manufacture sugar, ethanol, and spirit (Lott *et al*., 2018) as well as supports to paper and chipboard industry worldwide (Khan *et al*., 2017).

Sugarcane is the second main cash crop of Pakistan puts forth a strong impact on the welfare of the farming community as it contributes a large part of their earnings (Hassan *et al*., 2017). In Pakistan, sugarcane is cultivated on an area of 1,038,879 hectares with an average cane yield of 64.59 t ha^{-1} and sugar recovery of 9.89% (Annual Report, 2020, PSMA) and a total of 98.74% of the sugar is obtained from sugarcane to fulfill the domestic level requirement (Annual Report, 2020, PSMA). The average per hectare yield in Pakistan is not so much as in other sugarcane-producing countries of the world (Junejo *et al*., 2021). Whereas, the agro-ecological conditions in different parts of Pakistan are highly conducive to cane production. Among the numerous reasons that lower sugarcane yield in Pakistan, the one main cause for that, is the cultivation of unapproved and low-yielding varieties (Khan *et al*., 2018). In Pakistan, the majority of commercially cultivated sugarcane varieties are becoming obsolete and dropping their potential over time (Junejo *et al*., 2012) and our growers do not have the choice of the difference in their sugarcane crop with the latest better sugarcane varieties (Majeedano *et al*., 2003; Junejo *et al*., 2012). Sugarcane productivity could in no way be improved until and unless potential varieties accompanied by appropriate technologies are adopted by the growers (Khalid *et al*., 2014).

Improved varieties have an important part in the productivity enhancement of sugarcane (Memon *et al*., 2010) and there exists a broad perspective of sugarcane research and development in Pakistan quite the opposite to other top cane growing countries (Williams and Rehman, 2016). The existing situation of stagnant cane yield and sugar recovery in the country demands pragmatic efforts in varietal development programs to discover the potential of sugarcane lines through their assessment based on variation for yield and quality contributing attributes. In this regard, Tahir *et al*. (2014) recommended that in the indirect selection of varieties for cane yield it would be worthwhile that testing of sugarcane varieties should be formed on maximum tillers capacity, taller cane stalks, and greater sugar recovery. Conversely, the conciliation should be made with other parameters like purity, and internode length, whereby they display a negative indirect effect. Ochami and Ochieng (2020) reported that in the study area the cane yield of sugarcane varieties depends upon yield parameters; cane height, cane thickness, and the number of millable canes. Tyagi *et al*. (2012) reported that the selection of genotypes on account of preferred characteristics of cane and sugar yield such as the number of millable canes, cane weight, and cane height should be the decisive factor in the sugarcane varietal development program.

The adaptability of a variety to particular agro-climatic conditions of the area to recognize the maximum yield leads to its success (Prabhakar *et al*., 2012; Getaneh *et al*., 2015). Consensus of the growers and sugar mills for a variety now rests largely on its cane yield and quality potential. The selection of variety exclusively gets better the cane yield in the range of 28-60 percent (Kathiresan *et al*., 2001).

Therefore, for sustaining high cane and sugar productivity, it is peremptory to evaluate sugarcane lines for profit-oriented traits so that the inherent genetic potential of the newly developed sugarcane lines could be sorted out for yield and quality-related parameters before these are released as commercial varieties.

Keeping in view the importance of the study, newly developed sugarcane genotypes were evaluated for cane yield and quality associated parameters in agro-climatic conditions of Thatta, Pakistan to have the high cane, sucrose contents, resistance to biotic and abiotic stresses genotypes.

Materials and Methods

The experiments were conducted in plant crop for two consecutive years 2018-19 and 2019-20 during

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the autumn cropping season at Makli farm of PARC-National Sugar and Tropical Horticulture Research Institute (NSTHRI), Thatta, Pakistan (24^{O} 46'34.11" N, 67^{O} 53'10.72" E). The soil of the experimental site during 2018-19 was characterized as clay loam with pH (7.4), EC (0.93 dS m^{-1}), poorly available nitrogen (0.06%), and low available phosphorus (3.97 mg kg^{-1}), and adequate exchangeable potassium (232 mg kg^{-1}). While, during 2019-20, the soil of the site was clay loam with pH (7.7), EC (1.03 dS m^{-1}), poorly available nitrogen (0.04%), low available phosphorus (3.81 mg kg^{-1}), and adequate exchangeable potassium (224 mg kg^{-1}).

The plant material for this study was comprised of four newly developed sugarcane genotypes namely YtTh-1701, YtTh-1705, YtTh-1707, and YtTh-1730 developed from the exotic fuzz of China. The fuzz was obtained from Guang Zhou Sugar Industry Research Institute (GSRI), Guang Dong, China under Pak-China Cooperation Project on Agriculture, PARC, Islamabad. The cross name of each sugarcane fuzz was prefixed as Yt after the name of Yuetang district in Hunan province, China. The names of sugarcane genotypes developed through Yt named sugarcane fuzz were proposed as YtTh (Yt stands for Yuetang and Th for their development in Thatta). The trials were conducted in a randomized complete block design (RCBD) with three replications. The experimental plots consisted of 10 m long three rows having 4 m row to row spacing. Two bud sets of each sugarcane genotype were placed in furrows using an overlapping planting method and then covered with a thin layer of soil.

Recommended dosage (230:115:125 kg ha^{-1}) of N: P_2O_5: K_2O fertilizers were applied in the form of Urea, TSP, and SOP. The full fertilizer dose of all phosphorus, potassium, and 1/3 nitrogen was applied at the time of planting, whereas the remaining nitrogen in two equal splits was applied subsequently after 45 and 90 days of planting. The agronomic practices, *viz*. weeding and earthing up, etc as well as insect pest and disease management practices were done as per recommendation. Irrigations were given as and when necessary as per crop water requirements. The data on cane yield, yield components, *viz*. cane thickness, cane height, and the number of millable canes were recorded at harvest. Five canes of each sugarcane genotype were collected randomly from each replication for juice analysis. The juice quality parameters, *viz*. brix%, pol%, purity%, and commercial cane sugar percentage (CCS %) were recorded at harvest using standard procedures (Meade and Chen, 1977).

$$\text{Purity\%} = \frac{\text{Pol\%} \times 100}{\text{Brix\%}}$$

$$\text{CCS\%} = \{\text{Pol\%} - (\text{Brix\%} - \text{Pol\%}) \times 0.4\} \times 0.74$$

The collected data were statistically analyzed by using computer software Statistix version 8.1. Analysis of variance (ANOVA) was done for the characteristics under study. The differences between treatment means were tested for significance at alpha 0.05 by Tukey's Honestly Significant Difference (HSD) test according to Steel *et al*. (1997).

Results and Discussion

Combined analysis of variance of sugarcane genotypes for cane yield and yield parameters over two years presented in Table 1 indicated that mean squires of genotypes for cane thickness, height, millable canes and cane yield were significant at 0.05% level of probability. In case of years, the effect was non-significant for cane thickness and height, while, significant ($P<0.05$) for millable canes and cane yield. The interaction of years with genotypes was found non-significant for cane thickness, and cane height, whereas, significant ($P<0.05$) for millable canes and cane yield.

The mean data of all sugarcane genotypes for cane yield and yield related characters is presented in Table 3, which revealed that the genotype YtTh-1705 exhibited significantly higher mean cane thickness (30.83 mm), which was 17.67% greater over check variety Thatta-10 (25.38 mm) followed by YtTh-1707 and YtTh-1701 which remained statistically at par mean cane thickness of 28.97 and 28.47 mm, respectively. Moreover, YtTh-1730 showed minimum results with mean cane thickness of 24.83 mm. The effect of year on cane thickness of sugarcane genotypes was not pronounced, however, it was noticed that during evaluation in the year 2018-19 and 2019-20, all the sugarcane genotypes with exception of YtTh-1730 had produced thicker cane stalks as compared to check variety.

In case of height, all the genotypes showed variable behavior with respect to this trait. The genotype YtTh-

1701 possessed significantly taller canes of 318.72 cm length followed by check variety Thatta-10 and YtTh-1705, which showed statistically similar results with mean cane height of 315.88 and 312.56 cm, respectively. In contrast, the genotype YtTh-1707 displayed least values for mean cane height (264.58 cm).

The results in Table 3 indicated that all the sugarcane genotypes under test interacted differently with years. It was observed that millable canes 165.0 (000 ha^{-1}) were significantly highest in check variety Thatta-10 followed by YtTh-1705 which showed 145.83 millable canes (000 ha^{-1}). While, the sugarcane genotypes YtTh-1701, YtTh-1707 and YtTh-1730 displayed 67.68, 63.64 and 48.87 % less values of millable canes (000 ha^{-1}) as compared to check variety.

In case of cane yield highly encouraging results were achieved from all sugarcane genotypes except YtTh-1730 during the years 2018-19 and 2019-20. The data in Table 3 indicated that the genotype YtTh-1705 has proved to be promising by producing maximum mean cane yield of 150.84 t ha^{-1}, followed by YtTh-1707, YtTh-1701 and Thatta-10 with statistically on par mean cane yield of 145.42, 142.29 and 137.09 t ha^{-1}, respectively. The sugarcane genotype YtTh-1730 could not out yielded the check variety due to minimum mean cane yield of 104 t ha^{-1}. The effect of years on cane yield of genotypes was distinctive, it was noted that in 2018-19 comparatively greater cane yield was exhibited over the year 2019-20 (Table 3).

Table 1: *Mean square for cane yield and yield parameters of sugarcane genotypes at Makli farm, Thatta during 2018-19 and 2019-20.*

Source	DF	Mean square values			
		Cane thickness	Cane height	Millable canes	Cane yield
Replication	2	3.3555	1128.51	242.50	163.8
Genotype	4	38.4329*	3077.22*	5289.60*	1985.2*
Year	1	9.6107 NS	251.26 NS	2341.72*	37984.5*
Genotype x year	4	7.2893 NS	864.08 NS	2459.63*	638.1*
Error	18	3.6688	204.28	112.45	227.2

**, significant at 0.05%; NS, non-significant; df, degrees of freedom.*

Table 2: *Mean square for different quality parameters of sugarcane genotypes at Makli farm, Thatta during 2018-19 and 2019-20.*

Source	DF	Mean square values			
		Brix	Pol	Purity	CCS
Replication	2	12.2880	30.5424	139.321	0.38988
Genotype	4	1.2570 NS	1.3528 NS	2.320 NS	1.08453 NS
Year	1	5.7583 NS	18.2394*	175.301*	9.58228NS
Genotype x year	4	2.7294 NS	1.0874 NS	22.728 NS	1.80227 NS
Error	18	3.2480	1.5622	21.841	2.54586

**, significant at 0.05%, NS, non-significant, df, degrees of freedom.*

Table 3: *Cane yield and yield parameters data of sugarcane genotypes at Makli farm, Thatta during 2018-19 and 2019-20.*

Genotypes	Cane thickness (mm)		Mean	Cane height (cm)		Mean	Millable canes (000 ha^{-1})		Mean	Cane yield (t ha^{-1})		Mean
Year	2018-19	2019-20		2018-19	2019-20		2018-19	2019-20		2018-19	2019-20	
YtTh-1701	26.11	30.83	28.47 b	324.44	313.00	318.72 a	96.67 d	100.00 d	98.34 c	193.33 a	91.25 de	142.29a
YtTh-1705	31.33	30.33	30.83 a	303.66	321.33	312.56 a	106.67d	185.00 a	145.83b	186.67ab	115.00 cd	150.84a
YtTh-1707	29.11	28.83	28.97ab	278.82	250.33	264.58 c	96.67 d	105.00 d	100.83c	183.33 ab	107.50 cd	145.42a
YtTh-1730	24.33	25.33	24.83 c	282.89	303.99	293.44 b	126.67c	95.00 d	110.83c	128.33 c	81.25 e	104.79b
Thatta-10	24.77	25.99	25.38 c	329.77	301.99	315.88 a	150.00 b	180.00 a	165.0a	166.67 b	107.50 cd	137.09a
Mean	27.13	28.26	-	298.13	303.92	-	115.33 a	133.00 b	-	171.67 a	100.50 b	-

Means followed by the same letters in column and row did not differ significantly at P<0.05.

The inherent genetic potential of the sugarcane genotypes might have played role in higher and lower cane yield in this experiment. The sugarcane genotypes with striking intrinsic genetic makeup possess potential to generate acceptable outcomes for per hectare yield under certain set of environmental situation. Various workers (Kadam *et al*., 2004; Khaliq *et al*., 2018; Ali *et al*., 2020; Nishad and Kumar, 2020) have also exhibited alike trend of performance in different genotypes planted in equal set of agro-climatic conditions and reported variability in different agronomic and yield attributes together with the mention yield components. Higher cane yield in YtTh-1705 may possibly be on account of well coordinated association of thicker cane stalks, longer cane stalks and more number of millable canes. The genotype YtTh-1701 regardless of possessing relatively lesser millable canes produced better cane yield might be owing to combined effect of longer, thicker and heavier cane stalks. Moreover, the genotype YtTh-1707 in spite of bearing fairly shorter cane stalks gave encouraging yield probably because of the weighty millable canes which compensated the shorter stalk length and weight. The lowest cane yield in genotype YtTh-1730 could be attributed to thinner cane stalks which resulted in low weight of millable canes. Cane length and cane thickness parameters of a sugarcane variety are of much importance because that enable the stalk weight to contribute directly in final harvest (Naidu *et al*., 2007; Hussain *et al*., 2017). The formation of millable canes independently by varieties may possibly be linked to their tillering capacity and extent of tillers that mature to millable cane. The difference in number of millable canes among the investigated varieties is possibly because of their variable genetic makeup (Ochami and Ochieng, 2020). Similarly, various workers (Arain *et al*., 2011; Getaneh *et al*., 2015; Bughio *et al*., 2018; Endris, 2018; Ali *et al*., 2020; Junejo *et al*., 2021) have reported that cane yield in sugarcane is highly affected by cane length, cane diameter, cane population (millable cane), and potential of variety to make use of accessible resources and its genetic makeup response in a specified environment.

The mean squares computed through analysis of variance for brix, pol, purity and CCS are presented in Table 2 which showed that genotype effect was non-significant (P<0.05) with respects to all quality related traits. The effect of year was significant (P<0.05) for pol and purity, whereas, non-significant for brix and CCS. The years x genotypes interaction was also non significant for all same parameters at 0.05% levels of probability.

The data of sugarcane genotypes for quality parameters presented in Table 4 indicated that maximum mean brix (21.65%) was recorded from YtTh-1705 followed by check variety Thatta-10 with mean brix of 21.0%. While, the other investigated genotypes could not surpass YtTh-1705 and check variety in terms of mean brix content. In case of pol%, the genotype YtTh-1705 remained on top by producing maximum mean pol value of 18.40%. Check variety Thatta-10 displayed next better mean pol value (17.83%). There was a distinctive effect of years on pol of genotypes. The pol value was of the genotypes was considerably higher in the year 2018-19 compared to 2019-20 (Table 4).

In case of commercial cane sugar (CCS) the sugarcane genotype YtTh-1705 demonstrated maximum mean CCS of 12.08% against the check variety Thatta-10 which produced mean CCS (11.73%) and thus, YtTh-1705 exhibited 2.89% higher CCS over check variety. The CCS% in rest other sugarcane genotypes in trial was below than that of Thatta-10 (Table 4).

Table 4: *Quality parameters data of sugarcane genotypes at Makli farm, Thatta during 2018-19 and 2019-20.*

Genotypes	Brix (%)		Mean	Pol (%)		Mean	Purity (%)		Mean	CCS (%)		Mean
Year	2018-19	2019-20		2018-19	2019-20		2018-19	2019-20		2018-19	2019-20	
YtTh-1701	21.3	19.6	20.45	18.39	15.88	17.13	86.38	81.02	83.70	11.37	10.95	11.16
YtTh-1705	22.6	20.7	21.65	19.51	17.29	18.40	86.32	83.52	84.92	12.06	12.11	12.08
YtTh-1707	21.4	20.3	20.85	18.62	16.75	17.68	87.00	82.51	85.25	10.45	11.66	11.05
YtTh-1730	21.5	19.8	20.65	18.74	16.11	17.42	87.16	81.36	84.26	11.64	11.13	11.38
Thatta-10	21.0	21.0	21.00	18.26	17.40	17.83	86.95	82.85	84.90	11.33	12.14	11.73
Mean	21.56	20.88	-	18.70 a	16.68 b	-	86.76 a	82.45 b	-	11.59	11.37	-

Means followed by the same letters in column and row did not differ significantly at P<0.05.

All the studied sugarcane genotypes exhibited variable behavior with regards to quality parameters. The variability might be attributed to their different genetic makeup. This variation among the sugarcane genotypes may be ascribed to the high adoptability of the genotypes in the climatic condition of Thatta area which is regarded as highly conducive for sugarcane growth and breeding (Arain *et al*., 2011; Bughio *et al*., 2018; Junejo *et al*., 2021). The final measurement of sucrose level in a particular genotype is judged by computing commercial cane sugar percentage and sugar yield, which are of highly essential from miller's and breeder's perspective (Nadeem *et al*., 2008; Hussain *et al*., 2017). Highest CCS in YtTh-1705 was due to the well-coordinated interplay of birx, pol and purity values. While, the genotype YtTh-1730 despite having higher mean purity value exhibited lowest CCS because of low brix and pol values. Brix and pol values measured from sugarcane juice are main parameters in calculating CCS (Albertson and Christopher, 2004). Both are important qualitative parameters used for maturity judgment (Khalid *et al*., 2014). If the brix value of a genotype is high and sucrose content is less, correspondingly the purity value may be reduced, which eventually may decrease CCS. Different workers (Getaneh et al., 2015; Khan *et al*., 2018; Reddy *et al*., 2020) found high correlation in most of the quality parameters of sugarcane with each other. According to Shikanda *et al*. (2017) a higher purity value points to high sucrose content. They further reported that in sugarcane crop, pol % and purity % of cane juice possess the strong and positive association.

Conclusions and Recommendations

Among investigated sugarcane genotypes YtTh-1705 showed highly encouraging results in terms of cane yield and CCS%. It can be included in the gene pool for further varietal development studies.

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Novelty Statement

The yield and quality performance of different sugarcane genotypes developed from exotic sugarcane fuzz (true seed) of China has been presented in the paper which was not previously studied.

Author's Contribution

Riaz Noor Panhwar: Conceived the idea, conducted the experiments and prepared write-up of the original draft of the research paper.
Abdul Fatah Soomro: Provided guidance for execution of this research experiment and reviewed the paper.
Muhammad Chohan: Assisted in data collection of different agronomic parameters and soil sample analysis.
Illahi Bux Bhatti: Helped in data entry and statistical analysis for various traits.
Ali Hassan Mari: Assisted in data collection and analysis of different quality parameters.
Samia Arain: Helped in write-up of conclusion and review of literature collection.
Sagheer Ahmad: Reviewed and edited the manuscript also provided technical input in all steps.

Conflict of interest

The authors have declared no conflict of interest.

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