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Evaluation of Sugarcane Clones for High Cane and Sugar Yield Under Semi-Arid Conditions of Faisalabad, Pakistan

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ABSTRACT

A preliminary yield trial (N-III) consisting of nineteen sugarcane clones was evaluated in two independent sets along with two check varieties (HSF-240 and CPF-253), at Sugarcane Research Institute, Faisalabad, during the 2024-25 crop cycle to identify superior clones for cane and sugar yield potential. The experiment was carried out in a randomized complete block design (RCBD) with three replications. Triple-budded setts (TBS) were planted during October 2024 at a seed rate of 50,000 triple-budded setts (TBS) ha^{-1}. Data on germination percentage, plant population, cane yield, and sugar recovery were recorded and compared with check varieties using a two-sided Dunnett's multiple comparison test. In Set-1, none of the nine tested clones significantly outperformed both check varieties for cane yield, although FDP-22-18 (1248 Mnd $acre^{-1}$) and FDP-22-13 (1026 Mnd $acre^{-1}$) exhibited performance comparable to the checks. In Set-2, three clones, FDP-21-119 (1363 Mnd $acre^{-1}$), FDP-21-271 (1162 Mnd $acre^{-1}$), and FDP-21-214 (1076 Mnd $acre^{-1}$), significantly exceeded both check varieties in cane yield and also demonstrated superior germination and/or plant population. Based on their overall performance, these three clones were selected for advancement to the next stage of selection in sugarcane varital development program for further multi-location evaluation. The results revealed substantial genetic variability among the tested clones for yield-related traits under the semi-arid agro-climatic conditions of Faisalabad and highlight the potential of continued clonal selection for the development of improved sugarcane varieties.

Introduction

Sugarcane is an important cash crop of Pakistan and plays an important role in the up lift of socioeconomic conditions of the growers. Sugarcane is the biggest source of revenue to the government because this crop fetches billions of rupees to the government in the form of duties and taxes. In recent industrial advancement sugarcane is not only confined to sugar production, but its bi-products such as alcohol, chipboard, and dozens of others industrial chemical compound and can be manufactured during the sugarcane processing. (Nazir et al 2013). Punjab is the leading sugarcane producing province, with Faisalabad located in the heart of its semi-arid agro-ecological zone. During 2025-26, sugarcane production in Pakistan stood 89.450 million tonnes, cultivated over an area of 1.222 million hectares, having average cane yield of 73.2 t ha^{-1} (Government of Pakistan, 2026). Sustained improvement in cane and sugar yield relies on a systamatic varietal development pipeline, In which candidate clones advanced through successive evaluation stages seedling nursery, clonal selection, preliminary yield trial (PYT) and advanced yield trial (AYT) before a variety is finally recommended for commercial cultivation (Jackson, 2005).

The preliminary yield trial stage is a critical filter in for varietal development program of sugarcane: as it is the first stage at which clones are evaluated in replicated plots against established commercial check varieties, allowing breeders to statistically separate genuinely superior genotypes from those with only apparent, non-significant advantages (Afzal et al., 2024). The perameters recorded at this stage germination percentage, plant population, cane yield and sugar recovery are strongly interlinked; germination and early tillering are known to be reliable Indicators of eventual millable cane population and yield (Jain et al., 2006; Negi and Koujalagi, 2018), while cane yield and sucrose recovery together Confirm the commercial cane sugar (CCS) yield that ultimately governs a variety's economic value (Vigneshwari and Shanthi, 2023; Khan et al., 2003).

Genotypic differences in cane yield and its contributing traits have an important role to identify superior sugarcane clones during early selection stages. Abu-Ellail et al. (2020) evaluated twenty sugarcane clones across fresh crop and first ratoon crop cycles using a randomized complete block design. Their results revealed significant differences among genotypes for cane yield and associated agronomic traits, while genotype × crop-cycle interactions showed the importance of evaluating clones across successive crop cycles. The authors stressed the value of multi-stage selection for strengthening sugarcane varietal development programs.

The identification of superior sugarcane clones based on cane yield, sugar yield and quality perameters is an essential component for varietal improvement program. Ganapathy et al. (2024) evaluated early-maturing sugarcane clones for agronomic performance, cane yield, commercial cane sugar (CCS) yield and disease responses perameters. Their findings identified promising clones with improved yield and quality characteristics, which were recommended for further evaluation. These results support the importance of systematic clonal selection and advancement of superior genotypes through successive selection stages in sugarcane breeding programs.

Environmental variability Throughout the crop's long growth cycle spanning autumn planting through to harvest more than a year later further influences the expression of these traits (Zhao and Li, 2015). Clones must therefore be evaluated under the actual Prevalent weather conditions of the trial season to infer meaningful conclusions about their field adaptability (Ganapathy and Ravichandran, 2024).

The present study highlight the performance of nineteen sugarcane clones, tested in two sets against the local check varieties HSF-240 and CPF-253, with the objective of identifying clones combining high cane yield with acceptable sugar recovery for advancement to the next stage of the varietal development programme of sugarcane.

Materials and Methods

Experimental Site & Design

The study was conducted during 2024-2025 at the research farm of the Sugarcane Research Institute (SRI), Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan. The experimental site is located in the semi-arid agro-climatic zone of central Punjab at 31.4310° N latitude and 73.0695° E longitude. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Planting was carried out in October 2024 using a plot size of 3.0 m × 2.4 m and a seeding rate of 50,000 triple-budded setts per hectare.

Plant Material and Treatments

Nineteen sugarcane clones were evaluated along with two check varieties, HSF-240 (Check C-1) and CPF-253 (Check C-2), divided into two independent trial sets (Set-1 and Set-2) to incorporate the number of entries within a manageable block size. The complete list of entries is given in Table 1.

Table 1. Sugarcane clones evaluated under the Preliminary Yield Trial (N-III)

Set-1 Clones (9)	Set-2 Clones (10)
FDP-22-03	FDP-21-108
FDP-22-04	FDP-21-284
FDP-22-06	FDP-21-214
FDP-22-13	FDP-21-310
FDP-22-18	FDP-21-200
FDP-22-31	FDP-21-233
FDP-22-61	FDP-21-314
FDP-22-91	FDP-21-119
FDP-22-96	FDP-21-271
	FDP-21-212

Note: HSF-240 and CPF-253 were planted as check varieties in both Set-1 and Set-2.

Crop Husbandry and Data Recorded

Standard agronomic practices recommended for the semi-arid zone of Punjab were followed evenly across all plots, including recommended fertilizer application and irrigation scheduling. Germination percentage was recorded at 45 days-after-planting interval, plant population (canes per acre) was counted prior to harvest, and cane yield (maunds per acre) was recorded at harvest. Ten representative cane samples per plot were analyzed for juice quality to check sugar recovery percentage (Commercial Cane Sugar, CCS%) using the standard Australian formula, consistent with the method described in earlier trials at this institute (Mahmood-Ul-Hassan et al., 2020).

Weather Conditions During the Crop Cycle

The trial was planted in October 2024 and harvested in January 2026, covering a full crop cycle of approximately fifteen months. Table 2 contains the data of month-wise weather conditions maximum and minimum temperature, relative humidity and total rainfall prevailing at Faisalabad throughout this period. The crop faced a typical semi-arid seasonal pattern: a mild, dry winter shortly after planting (November 2024–February 2025), a hot, dry pre-monsoon period (April–June 2025) occuring alongside with the tillering and grand-growth phase, a humid monsoon spell (July–September 2025) supplying the bulk of the season's rainfall, and a second cool, dry winter (November 2025–January 2026) leading into harvest. Such seasonal variations in temperature and rainfall are known to significantly influence germination, tillering and final cane yield in sugarcane (Zhao and Li, 2015; Ganapathy and Ravichandran, 2024).

Table 2. Weather parameters during the crop cycle (October 2024 – January 2026)

Month	Max. Temp (°C)	Min. Temp (°C)	Relative Humidity (%) at 5 pm	Total Rainfall (mm)
October, 2024	34.0	20.5	42	8
November, 2024	27.0	13.0	50	3
December, 2024	22.0	7.5	58	5
January, 2025	19.5	6.5	63	18
February, 2025	22.5	9.0	55	22
March, 2025	27.5	13.5	46	20
April, 2025	34.0	19.0	33	10
May, 2025	39.5	24.0	22	12
June, 2025	41.5	27.5	20	25
July, 2025	37.5	28.0	58	110
August, 2025	36.5	27.5	62	95
September, 2025	35.5	24.5	53	45
October, 2025	33.5	19.0	40	6
November, 2025	27.0	12.5	49	3
December, 2025	21.5	7.0	57	4
January, 2026	19.0	6.5	63	15

The monthly climatic data for Faisalabad during the corresponding crop cycle were obtained from the Physiology Department, Agronomic Research Institute (ARI), Faisalabad.

Statistical Analysis

Data were statistically analyzed using Statistix 8.1 software (McGraw-Hill, 2008). The two-sided Dunnett's Multiple Comparisons test was applied to compare each tested clone against both check varieties simultaneously. In the tables of results, a single asterisk (*) denotes a value significantly better than one of two check varieties, while a double asterisk (**) indicate a value significantly better than both check varieties, consistent with standard reporting convention for this trial series (Afzal et al., 2024).

Results and Discussion

Set-1 Performance

The performance of the nine clones tested in Set-1, were compared with checks HSF-240 and CPF-253, is presented in Table 3. Germination percentage ranged from 36.0% (FDP-22-61) to 56.7% (FDP-22-06), while both checks exibited comparitively higher germination rate (CPF-253: 47.0%; HSF-240: 51.3%). For plant population, FDP 22-03 recorded a significant betetr (54,074 plants/acre) over one of the checks, indicating better initial performance, however, this did not consistently translate into a yield performance.

For cane yield, the check varieties performed better, with CPF-253 (1131 mnd/acre) and HSF-240 (1243 mnd/acre) placing among the highest values recorded in this set. FDP-22-18 produced the closest competing yield (1248 Mnd/acre), marginally exceeding both checks numerically, followed by FDP-22-13 (1026 Mnd/acre); however, neither difference reached the level of statistical significance defined by critical value of experiment for comparison (285 Mnd/acre), and consequently no clone in Set-1 is flagged with a significance star for yield. Sugar recovery in Set-1 was generally lower among the tested clones (10.25–11.80%) than in the check varieties (CPF-253: 12.98%; HSF-240: 12.83%), a pattern constant with earlier observations that newly introduced or early-generation clones often remain behind well-established commercial checks in sucrose accumulation despite competitive cane yield (Jackson, 2005; Vigneshwari and Shanthi, 2023). On the basis of this first evaluation, none of the clones from Set-1 met the threshold for advancement to the next selection stage.

Table 3. Performance of Set-1 clones in comparison to check varieties HSF-240 and CPF-253

Sr#	Name of Clone	Germination (%)	Population/Acre	Yield (Mnd/Acre)	Sugar Recovery (%)
1	FDP-22-03	45.3	54074*	871	11.74
2	CPF-253 (Check)	47.0	36482	1131	12.98
3	FDP-22-04	46.7	51111	911	11.12
4	FDP-22-06	56.7	39815	643	11.64
5	FDP-22-13	45.0	38333	1026	11.34
6	FDP-22-18	43.3	34630	1248	12.45
7	FDP-22-31	36.7	33704	601	10.25
8	FDP-22-61	36.0	39259	721	11.66
9	FDP-22-91	54.7	48148	951	11.45
10	HSF-240 (Check)	51.3	35371	1243	12.83
11	FDP-22-96	51.3	34445	733	11.80
Critical Value for Comparison	11.206	16181	285	0.4970	
Standard Error of Difference	4.24	6135	108	0.188	
Coefficient of Variation (%)	11.4	18.56	14.49	1.96	

Set-2 Performance

Set-2 (Table 4) proved considerably greater variability and a greater number of statistically significant differances than Set-1, as showed by its substantially lower critical value for comparison (82.03 Mnd/acre for yield, versus 285 in Set-1), indicating tighter experimental precision in this set. Germination percentage varied widely, from 29% (FDP-21-214) to 68% (FDP-21-108), with the latter significantly exceeding both checks (68**). Several clones FDP-21-284 (63%**), FDP-21-310 (52%**) and FDP-21-314 (50%**) also exhibited significantly higher germination than both checks, while CPF-253 (44%*) and HSF-240 (38%) recorded the lower germination among the checks.

Plant population followed a broadly similar pattern, with FDP-21-108 (39,213**), FDP-21-214 (47,374**), FDP-21-200 (41,672**) and FDP-21-233 (41,087**) all significantly exceeding both check varieties. Notably, FDP-21-214 combined the highest population in the set with a competitive yield, suggesting efficient conversion of tillering capacity into millable canes.

The most decisive results emerged for cane yield. Three clones significantly outyielded both check varieties: FDP-21-119 (1363 Mnd/acre**), FDP-21-271 (1162 Mnd/acre**) and FDP-21-214 (1076 Mnd/acre**), with a further clone, FDP-21-314 (1039 Mnd/acre**), also crossing the double-check significance threshold. In comparison, the check varieties yielded only 871 (CPF-253) and 932 (HSF-240) Mnd/acre in this set. FDP-21-119 in particular surpassed HSF-240 by approximately 46% and CPF-253 by over 56% in cane yield, while maintaining a respectable sugar recovery of 11.25%. For sugar recovery, HSF-240 (12.88%*) recorded the single highest value in the set, marginally ahead of CPF-253 (12.38%), while several test clones notably FDP-21-310 (12.43%) and FDP-21-271 (12.51%) remained close to check-level sucrose content despite their substantially higher cane yield, indicating that high yield in this set was not achieved entirely at the expense of sugar quality.

Table 4. Performance of Set-2 clones in comparison with check varieties HSF-240 and CPF-253

Sr#	Name of Clone	Germination (%)	Population/Acre	Yield (Mnd/Acre)	Sugar Recovery (%)
1	FDP-21-108	68**	39213**	941	11.11
2	CPF-253 (Check)	44*	36704	871	12.38
3	FDP-21-284	63**	27541	910	10.83
4	FDP-21-214	29	47374**	1076**	12.12
5	FDP-21-310	52**	36639	736	12.43
6	FDP-21-200	42*	41672**	734	10.99
7	FDP-21-233	45*	41087**	898	11.26
8	FDP-21-314	50**	36247	1039**	12.06
9	FDP-21-119	43*	36605	1363**	11.25
10	FDP-21-271	39	27207	1162**	12.51
11	HSF-240 (Check)	38	34381	932	12.88*
12	FDP-21-212	44*	33846	841	11.44
Critical Value for Comparison	2.289	2339	82.03	0.328	
Standard Error of Difference	0.863	882	30.93	0.124	
Coefficient of Variation (%)	2.28	2.96	3.95	1.29	

The strong and stable double-check significance for cane yield recorded by FDP-21-119, FDP-21-271 and FDP-21-214 combined with either superior germination, better population provides robust statistical support for advancing these three clones to the Advanced Yield Trial stage in coridnation with the standard practice of prioritizing clones with significant, repeatable yield advantages over both commercial checks simultaneously rather than over only one (Gravois et al., 1991; Milligan et al., 1996).

Discussion

The gap between Set-1 and Set-2 shows the importance of testing precision in correctly identifying superior clones. Set-2's lower CV (2.28–3.95% for most traits, versus 11.4–18.56% in Set-1) allowed finer discrimination between clones and checks, enabling to find significant differences that a noisier trial would have missed. These results align with earlier work emphasizing that indirect selection based on early yield-component traits is only reliable when experimental error is well controlled (Gravois et al., 1991; Milligan et al., 1996).

The positive association observed between germination/population and final cane yield in several Set-2 clones (e.g., FDP-21-214, FDP-21-108) support earlier findings that early crop establishment traits are useful indirect selection criteria in sugarcane breeding programs (Jain et al., 2006; Negi and Koujalagi, 2018; Panhwar et al., 2022). However, the case of FDP-21-119 which achieved the highest yield in the entire trial without a significant germination or population advantage also confirms that yield in sugarcane is a complex trait regulated by additional components such as single cane weight and stalk elongation during the grand growth period, which coincided with the hot, dry pre-monsoon months of April–June 2025 (Table 2) and the subsequent monsoon rains of July–September 2025 that likely supported better cane elongation (Arain et al., 2011; Khan et al., 2003).

Tolera et al. (2024) found substantial genetic variability among sugarcane genotypes and explained the importance of yield contributing traits, including stalk number and stalk length, in identifying superior genotypes for sugarcane improvement. These results in in cordination with these findings.

Ganapathy et al. (2025) studied an early maturing sugarcane clone across plant-cane and ratoon yield trials and reported superior cane yield, commercial cane sugar (CCS) yield and sucrose content compared with standard checks. Their findings support the importance of successive yield evaluation before varietal advancement.

The generally lower sugar recovery of high-yielding test clones relative to the check varieties, particularly in Set-1, reflects a widely reported trade-off between vegetative cane yield and sucrose accumulation in early-generation sugarcane clones (Jackson, 2005; Ganapathy and Ravichandran, 2024). This trade-off highlights the value of the multi-stage selection clones such as FDP-21-119, FDP-21-271 and FDP-21-214, which combine significant yield superiority with sugar recovery noticeably near to the check varieties, represent a more balanced advancement candidate than clones with high yield alone.

Conclusion

This preliminary yield trial assessed nineteen sugarcane clones in comparison to two check varieties under the semi-arid conditions of Faisalabad. While none of the nine clones in Set-1 showed a statistically significant yield advantage over check varieties, three clones from Set-2 FDP-21-119, FDP-21-271 and FDP-21-214 exhbited cane yield significantly higher than both HSF-240 and CPF-253, alongside acceptable sugar recovery and superior germination or population. These three clones have been promoted to the Advanced Yield Trial stage for further testing and multi-location expermentation to confirm their yield stability, adaptability and economic feasibility before thier potential varietal release. Continued preliminary and advanced yield trials of this nature remain essential to to maintain genetic progress in Pakistan's sugarcane breeding program.

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