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## PERFORMANCE OF FIRST SUGARCANE RATOON CLONES FROM A POLY-CROSS OF POJ 2878: AGRONOMIC AND SUGAR YIELD EVALUATION AT KARANGPLOSO MALANG, INDONESIA

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### SUMMARY

Sugarcane (*Saccharum officinarum* L.) productivity has not yet fulfilled the domestic sugar demand; therefore, increasing productivity is necessary in Indonesia. However, addressing this issue can proceed through the development of new, superior sugarcane cultivars. The following study aimed to obtain ratoon crop (RC-1) clones derived through polycross with higher sugar yields than their female parent. The research ran from December 2021 to November 2022 at the Karangploso Experimental Station, Malang, Indonesia. Twenty-four clones resulted from crossing cultivar POJ 2878 with three other parental cultivars, Bululawang, 6535, and SIL-04, and one female parent. The study employed a randomized complete block design (RCBD) with two replications, using plots measuring 1 m × 5 m and a planting spacing of 110 cm. Based on the results, the 10 obtained sugarcane clones produced by polycross have the potential to increase sugarcane productivity (e.g., 19/P5/37, 19/P5/33, and 19/P5/27), which outperformed POJ 2878 consistently in stalk length, diameter, and weight, the number of stalks, and cane and sugar yield. Clones 19/P5/37, 19/P5/33, and 19/P5/27 exhibited increases in sugar yield of 11.57%, 10.28%, and 10.02%, respectively, compared with POJ 2878, suggesting higher production potential than the control.

**Keywords:** Sugarcane (*S. officinarum* L.), hybridization, polycross, clonal selection, sugar yield, ratoon crop, cultivar POJ 2878

**Key findings:** Eighteen sugarcane (*S. officinarum* L.) clones, obtained from the polycross of the cultivar POJ 2878 with three other parental genotypes, Bululawang, 6535, and SIL-04, along with one female parent clone, showed potential for high cane productivity.

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## INTRODUCTION

Indonesia is yet to meet domestic sugar demand, with a self-sufficiency ratio (SSR) of 34% (Agricultural Data and Information Center, Ministry of Agriculture, 2025). However, over the past five years, the domestic sugar production has averaged only 2.191 million tons. As a result, the country imports sugar to meet the shortfall in consumption (Iryani *et al.*, 2012; Inayaturohmah *et al.*, 2023). Low sugarcane (*Saccharum officinarum* L.) production can be due to several factors. These include the limited availability and adoption of high-yielding sugarcane cultivars, unpredictable weather and climatic conditions, land-use competition with other crops and non-agricultural purposes, and the emergence of new pests and diseases affecting the sugarcane crop (Toharisman and Triantarti, 2016). With these challenges, improving sugarcane productivity and enhancing sugar yield is a critical strategies for achieving national self-sufficiency in sugar production and reducing dependency on imports.

The choice of polycross had the hope that superior traits from male parents can be collected in female parents. Likewise, the new superior cultivars can be outcomes from considerably increased yield compared with their female parents, with the said methodology proven effective in various crop improvement programs (Tew and Pan, 2010). The sugarcane cultivar POJ 2878 is a superior genotype in Indonesia, which is also a commonly used important parental genotype in crosses worldwide to get sugarcane offspring with superior yield-related traits under diverse environmental conditions (Davis, 1951; Lu *et al.*, 2024; Wang *et al.*, 2025). The Bululawang is the mid-late ripening sugarcane cultivar with high crush yield and high adaptability to growing environments, and its characteristics are increasingly essential in modern sugarcane breeding programs (Widyasari *et al.*, 2022). Sugarcane genotypes SIL-04 and clone 6535 also have the potential for high cane yield and sugar production, representing promising genetic resources for future breeding programs (Yulaikah *et al.*, 2023; Djumali *et al.*, 2024).

The polycross between the cultivar POJ 2878 and the three male parental genotypes intends to obtain new superior cultivars with higher sugarcane yield than POJ 2878, following the established principles of heterosis in sugarcane breeding.

Sugarcane plants are ratoonable, and the recommended ratooning is possible up to the fourth ratoon (RC-4). Past studies also reported most sugarcane plantation areas have ratoon crops (80%), highlighting the crucial importance of ratooning ability in commercial sugarcane production (Xu *et al.*, 2021; Dlamini *et al.*, 2024). Therefore, the presented study aimed to obtain RC-1 sugarcane clones from the polycross that produce higher sugar yield than their female parent and address the need for improved ratoon performance in modern cultivation systems.

## MATERIALS AND METHODS

### Crop husbandry and procedure

A polycross of POJ 2878 x (Bululawang, 6535, and SIL-04) commenced in 2019, resulting in 148 growing individuals, with 24 sugarcane (*S. officinarum* L.) clones identified with higher sugar yield than their parental genotypes in 2020. The concerned research ran from December 2021 to November 2022 at the Karangploso Experimental Station, Malang, Indonesia, under the weather and soil conditions presented in Tables 1 and 2. The planting material was the RC-1 plants of 24 clones from the polycross of POJ 2878 x (Bululawang, 6535, and SIL-04) and one female parent clone. The 24 clones underwent selection in 2020 from the crosses made in 2019. The sugarcane crossed clones and the cultivars had a randomized complete block design arrangement with two replications for comparison. Each sugarcane clone and the cultivar in a replication comprised one row measuring 5 m in length (Figure 1). The row spacing (measured from center to center of each sugarcane row) was 110 cm, resulting in a total sugarcane row length per hectare (row factor) of 8100 m.

**Table 1.** Site weather conditions.

Climatological Elements	2021					2022						
	Dec	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov
Temperature (°C)	24.4	24.1	23.9	24.2	24.2	24.7	23.4	23.1	23.3	23.9	23.6	23.9
Relative Humidity (%)	84	81	82	83	78	77	80	75	76	78	85	84
Rainfall (mm)	215	216	353	349	354	75	308	20	44	127	496	474
Rainy days (days)	24	25	24	26	22	14	19	4	9	12	24	27

**Table 2.** Soil characteristics of the research site.

Soil chemical and texture characteristics	Value	Categories
pH 1:1		
- H <sub>2</sub> O	5.6	Slightly acid
- KCl 1N	5.3	
C-organic (%)	1.56	Very low
N total (%)	0.14	Low
C/N	11.0	Low
P <sub>2</sub> O <sub>5</sub> Bray (mg.kg <sup>-1</sup> )	3.05	Low
K NH <sub>4</sub> OAC1N pH:7 (me/100g)	0.12	Low
Na NH <sub>4</sub> OAC1N pH:7 (me/100g)	0.90	Low
Ca NH <sub>4</sub> OAC1N pH:7 (me/100g)	15.04	Medium
Mg NH <sub>4</sub> OAC1N pH:7 (me/100g)	0.54	Medium
CEC NH <sub>4</sub> OAC1N pH:7 (me/100g)	30.60	Medium
Total base (me/100g)	16.60	Low
Base saturation	54	Medium
Texture:		Silty clay
- Sand (%)	6	
- Silt (%)	45	
- Clay (%)	49	



**Figure 1.** RC-1 polycross population in the field research.

Plant maintenance included land clearing, trimming, root pruning and removal, fertilization, weeding, bulking, irrigation, shoot thinning, and pest control. Fertilization took place at 3–4 weeks and again at 3–4 months in furrows, using a dosage of 600 kg Phonska and

500 kg ZA. Phonska fertilizer application occurred during the first fertilization, and ZA fertilizer was during the second. Irrigation proceeded when the plants showed signs of temporary wilting. Pest and disease control depended on the severity of the infestation in

the field. Clipping transpired as needed by removing dry leaves according to the plant's condition. Harvesting ensued after 12 months of trimming by cutting the plants at the base of the stalk, with the stalks topped and stripped of dry leaves. Clean stalks collected entailed weighing to determine the stalk weight per plot.

### Data recorded and statistical analysis

An observation on the number of stalks per meter of row (JBM) preceded harvest by counting all stalks (JB) within all plots. The number of stalks per meter of row (JBM) underwent calculations using the formula:

$$JBM = JB / (\text{total row length})$$

Observations of stalk length, diameter, and weight were conducted at harvest by taking 10 harvested stalks per plot as sample plants for measuring length and diameter. Stalk weight determination continued by weighing the entire sample plant, while juice yield measurement was after extracting juice from the sample plants. The extracted juice then received analysis to determine juice weight, Brix, and Pol values. The calculation of juice extraction factor (FP) used the formula below

$$\text{Juice Extraction Factor (FP)} = \text{Juice Weight} / \text{Stem Weight}$$

The non-sugar value (NN) computation was  $NN = 0.4 \times (\text{Brix} - \text{Pol})$ , with the yield percentage calculated using  $\text{Yield (\%)} = \text{FP} \times \text{NN}$ . Furthermore, the sugarcane yield and crystal sugar yield (sugar yield) estimations used the following formulas:

$$\text{Sugarcane yield (t ha}^{-1}\text{)} = 8100 \times (\text{Stem Weight per Plot}) / (\text{Total Plot Length})$$

$$\text{Sugar yield (t ha}^{-1}\text{)} = \text{Sugarcane yield} \times \text{Yield (\%)}$$

All the data underwent the analysis of variance and continued with Duncan's multiple range test (HSD) at the 5% level using PKBT-STAT 3.2 software. In determining the effect of stalk length and diameter on stalk weight, the number of stalks and stalk weight on

sugarcane yield, as well as yield and sugarcane yield on sugar yield, stepwise analysis succeeded. The expression of the value of the correlation coefficient multiplied by 100% was the total effect of the two components on stalk weight, sugarcane yield, and grain yield. The stepwise analysis also determined the contribution of each component variable to stalk weight, sugarcane yield, and grain yield.

### RESULTS

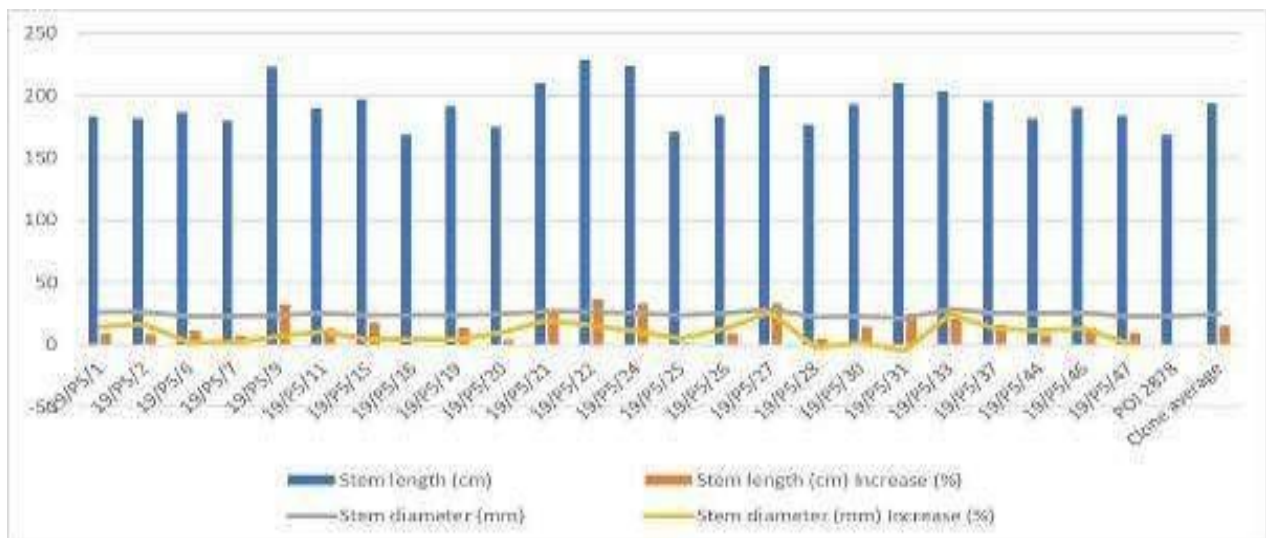
The analysis of variance showed different varietal effects ( $p \leq 0.01$ ) for all characteristics measured in the first ratoon (RC-1) of the sugarcane (*S. officinarum* L.) population from the polycross of POJ 2878. These effects were highly significant. The traits for which significant differences appeared included stalk length, diameter, and weight; the number of stalks per hectare, cane yield, sucrose content, and sugar yield (Table 3). The variation coefficients were between 2.19% and 9.03%, which is a sign of good precision in the experiment.

Assessing the performance of the RC-1 polycrossed clones revealed remarkable differences in stalk structure and yield factors (Table 3; Figure 2). The majority of the clones showed longer stalks than the control variety, POJ 2878. Clones 19/P5/22, 19/P5/24, and 19/P5/27 were the tallest among all the clones, the heights being above 220 cm, thus much taller than the POJ 2878 (168.02 cm) at a statistically significant level. On the other hand, the height of some clones, such as 19/P5/16, 19/P5/20, 19/P5/25, and 19/P5/28, was equal to the height of the control or only slightly greater, which suggested a very limited improvement in this trait.

The difference in stalk diameter among the clones was quite significant. The greatest stalk diameters was observed in 19/P5/27 (28.56 mm) and 19/P5/33 (28.27 mm), in comparison to POJ 2878 with 22.62 mm. Other clones, including 19/P5/21 and 19/P5/22, showed more than the control for stalk diameter as well. The simultaneous elevation in length and diameter of stalks among most RC-1 clones is an indicator that the main

**Table 3.** Agronomic and yield characteristics of sugarcane clones.

Clones	Stalk length (cm)	Stalk diameter (mm)	Stalk weight (kg)	Stalks/ha	Sugarcane yield (t/ha)	Yield (%)	Sugar yield (t/ha)
19/P5/1	183.23	25.95	1.04	89100	92.83	10.65	9.92
19/P5/2	181.02	26.29	1.05	75735	79.85	9.94	7.94
19/P5/6	186.25	22.96	0.82	91530	75.99	10.89	8.13
19/P5/7	179.46	22.97	0.80	78570	62.50	10.53	6.55
19/P5/9	222.40	24.07	1.09	74723	81.63	9.82	7.89
19/P5/11	189.17	25.06	1.00	65610	65.85	10.30	6.70
19/P5/15	197.06	23.50	0.92	94886	87.72	10.06	8.74
19/P5/16	168.33	23.59	0.79	75330	59.41	9.94	5.89
19/P5/19	191.07	23.65	0.90	82620	75.01	10.89	8.07
19/P5/20	174.69	24.80	0.91	54450	49.49	10.65	5.24
19/P5/21	209.38	27.17	1.30	71280	92.83	10.77	9.97
19/P5/22	228.54	26.13	1.31	64800	85.08	11.60	9.87
19/P5/24	223.44	25.02	1.18	67950	80.87	10.42	8.42
19/P5/25	170.52	23.79	0.81	52650	43.06	9.94	4.26
19/P5/26	183.35	25.52	1.00	49613	49.83	10.30	5.13
19/P5/27	223.63	28.56	1.53	66600	102.33	9.82	10.02
19/P5/28	176.27	22.06	0.72	64530	46.47	8.99	4.16
19/P5/30	192.50	23.07	0.87	80393	70.20	9.70	6.81
19/P5/31	209.55	21.53	0.82	82620	67.53	10.18	6.83
19/P5/33	203.10	28.27	1.37	67950	93.13	11.13	10.28
19/P5/37	195.42	25.58	1.08	100238	108.09	10.77	11.57
19/P5/44	181.46	25.21	0.97	76950	75.64	10.30	7.77
19/P5/46	190.31	25.68	1.05	53923	57.12	10.30	5.87
19/P5/47	183.54	22.90	0.81	73710	59.69	11.13	6.59
POJ 2878	168.02	22.62	0.72	55080	39.87	11.48	4.57
Clone means	192.47	24.64	1.01	73157	73.42	10.38	7.61
HSD 5%	17.54	2.68	0.27	21643	26.21	2.02	2.82
CV (%)	2.19	2.62	6.42	7.17	8.73	4.65	9.03



**Figure 2.** The Bar diagram showing stalk length and stalk diameter of the first ratoon sugarcane (RC-1) clones obtained from polycross and their increasing to POJ 2878.

morphological features responsible for biomass accumulation, as shown in Figure 2, gained simultaneous improvements.

The morphological differences in stalks were, more or less, the same as the stalk weight differences. The heaviest stalks came from clone 19/P5/27 (1.53 kg per stalk) and clone 19/P5/33 (1.37 kg per stalk). Conversely, POJ 2878 produced rather light stalks (0.72 kg per stalk). The majority of RC-1 clones were producing heavier stalks than the control; however, the clones 19/P5/6, 19/P5/7, 19/P5/16, 19/P5/25, 19/P5/28, 19/P5/30, 19/P5/31, and 19/P5/47 had stalk weights similar to that of POJ 2878, thus confirming the existence of different responses among the offspring.

The number of stalks per hectare showed significant differences as well. The clones 19/P5/37 and 19/P5/15 were the ones with the most stalks, each having more than 94,000 stalks per hectare, while POJ 2878 had only 55,080 stalks/ha. The combination of stalk weight and density led to the stalk differences in cane yield among the RC-1 clones. Cane yield was between 43.06 and 108.09 t/ha. Clone 19/P5/37 reached the peak cane yield of 108.09 t/ha, followed by clones 19/P5/27 (102.33 t/ha) and 19/P5/33 (93.13 t/ha), which are nearly two to three times higher than POJ 2878 (39.87 t/ha). In contrast, some clones like 19/P5/20, 19/P5/25, 19/P5/26, and 19/P5/28 had cane yields similar to or just slightly above the control, which suggests a small yield increase existed.

The variation of sucrose content in clones was moderate; the range was from 8.99% to 11.60%. Clone 19/P5/22 had the highest sucrose content of 11.60%, followed by POJ 2878 with 11.48%. Clones 19/P5/33 and 19/P5/47 each had a sucrose content of 11.13%. The results suggest most RC-1 clones held sugar content on par with the control, which implies the increase in yield was not totally at the cost of juice quality.

The sugar yield per hectare, together with sucrose content and cane yield, gave a clearer separation among the clones. Clone 19/P5/37 scored the highest sugar yield (11.57 t/ha), and clones 19/P5/33 (10.28 t/ha) and

19/P5/27 (10.02 t/ha) followed. Several more clones, such as 19/P5/1, 19/P5/21, and 19/P5/22, also had sugar yields significantly higher than POJ 2878 (4.57 t/ha). In contrast, clones 19/P5/25 and 19/P5/28 revealed sugar yields lower than the control, pointing out that not all the polycross-derived progenies were beneficial for sugar production.

The backward stepwise analysis relationship of stalk weight (SW) with stalk length (SL) and stalk diameter (SD) resulted, which formed the equation  $SW = 0.8056 SL + 1.5587 SD - 1.3758$ , with a correlation coefficient of 0.997. The relationship between sugarcane yield (CY) and the weight (SW) and number of millable canes (NMC) of stalks comprised the regression equation  $CY = 0.9841 SW + 0.8949 NMC - 0.6193$ , with a correlation coefficient of 0.997.

In general, the majority of the RC-1 clones showed better performance agronomically and in terms of yield when compared to the POJ 2878 variety. This was due mainly to the factors of increased stalk weight and higher stalk density, which were very much responsible for better cane and sugar yield (Table 4). The clones 19/P5/37, 19/P5/33, and 19/P5/27 were those always behaving the best, while some clones showed only slight improvement, and very few clones were worse than the control.

## DISCUSSION

The first evaluation of sugarcane (*S. officinarum* L.) clones from the polycross of POJ 2878 with three other parental cultivars (Bululawang, 6535, and SIL-04) showed the breeding method was successful in producing a wide range of phenotypes for agronomic and yield-related traits. The majority of the RC-1 clones were superior to the female parent in most important traits, mainly stalk type, stalk weight, the number of millable canes, and, finally, cane and sugar yield. This study's results verified that polycross breeding is still an effective method for mixing and discovering good alleles in the sugarcane breeding programs.

**Table 4.** Increase in stalk weight, the number of millable stalks, sugarcane yield, yield, and sugar yield of first ratoon (RC-1) sugarcane clones derived from polycross, compared to POJ 2878.

Clones	Increase (%)				
	Stalk weight	Stalks/ha	Sugarcane	Yield	Sugar yield
19/P5/1	42.31	60.76	126.70	-7.27	113.41
19/P5/2	44.40	36.97	95.98	-13.60	71.67
19/P5/6	13.81	64.87	85.79	-5.33	75.53
19/P5/7	9.88	41.93	54.36	-8.43	42.46
19/P5/9	49.27	35.20	99.45	-14.76	70.64
19/P5/11	37.21	18.70	61.92	-10.56	45.31
19/P5/15	26.40	71.22	114.13	-12.63	88.52
19/P5/16	8.77	36.26	46.94	-13.63	28.29
19/P5/19	23.80	49.16	83.67	-5.30	74.42
19/P5/20	24.46	-1.14	22.86	-7.36	14.26
19/P5/21	77.58	28.99	127.04	-6.29	115.04
19/P5/22	79.30	17.44	108.65	1.10	112.88
19/P5/24	61.27	22.95	97.61	-9.40	81.51
19/P5/25	12.03	-4.41	7.35	-13.63	-6.62
19/P5/26	37.76	-9.77	23.98	-10.46	11.93
19/P5/27	108.96	20.61	149.82	-14.70	116.03
19/P5/28	-0.18	16.88	16.04	-22.09	-8.37
19/P5/30	18.98	45.20	72.04	-15.70	47.28
19/P5/31	12.66	49.33	66.42	-11.60	48.48
19/P5/33	86.42	22.95	127.48	-3.20	121.64
19/P5/37	47.49	80.83	163.44	-6.33	149.12
19/P5/44	33.33	38.91	84.85	-10.46	67.52
19/P5/46	44.72	-2.23	40.92	-10.46	27.41
19/P5/47	11.60	33.28	47.56	-3.23	43.35
POJ 2878					
Clone means	39.20	32.82	84.17	-9.64	66.66
HSD 5%	33.9	38.37	57.25	17.85	57.31

Note: Means followed by the same letter in the same column are not significantly different according to the 5% HSD test. A minus sign (-) in the increase (%) column indicates a decrease compared to POJ 2878.

A clear differentiation in performance among RC-1 clones was evident. The topmost clones, for instance, those numbered 19/P5/37, 19/P5/33, and 19/P5/27, were always emerging as the top performers with remarkably massive cane yields (>90–100 t/ha) and sugar yields, which were more than those of POJ 2878 by a wide margin. Furthermore, several other clones (e.g., 19/P5/1, 19/P5/6, 19/P5/15, 19/P5/19, 19/P5/21, 19/P5/22, and 19/P5/24) have links to showing yield advantages; however, their performance was not as great as that of the top-ranking clones. On the contrary, a couple of the clones (19/P5/25 and 19/P5/28) did not

beat the control and thus were also leaning on the side of lower yields for both cane and sugar. The dissection of the clones into superior, moderately improved, and inferior-performance groups confirms the power of early-generation selection in the evaluated population.

The superior performance of the highest-yielding RC-1 clones showed a primary association with improvements in stalk morphology. In general, the highest-yielding clones had either longer or thicker stalks than POJ 2878, which resulted in heavier stalk weight and better stand structure. These findings align with the idea that carbohydrate

partitioning toward the stalk is a key factor in sugarcane yield. The control mostly on the distribution of assimilates among roots, stalks, and leaves was due to the differences in plant genotypes (Wang *et al.*, 2013; Diana *et al.*, 2020; Liu *et al.*, 2020). Conducting regression analysis with stalk weight and the number of millable canes as variables gave new analytic views on the total amount of cane yield their interaction produced. The fitted model revealed a very close correlation between the predicted and observed yields of cane, which implies these two factors were mainly responsible for the explained variation.

Besides the stalk weight, the number of millable canes per hectare succeeded in its discovery as a vital factor for cane yield. The top clones had thick stalks and high stalk density simultaneously, while the clones lacking any of the two produced lower yields. It is possible to interpret the association of stalk population and yield by comparing their differences in tiller survival and carbohydrate availability during the vegetative phase. The tillers that are given insufficient assimilates usually cannot grow to be millable canes, but those that have a good supply of carbohydrates will survive and increase the yield (Khan *et al.*, 2022). The reason is the influence on tillering capacity and assimilate production by the genotype-specific photosynthetic efficiency and growth vigor (Leanasawat *et al.*, 2021; Saleem *et al.*, 2023); hence, genetics largely determine the number of millable canes harvested (Yadawad *et al.*, 2022). Such is the case of high stalk density noted in clones like 19/P5/37 and 19/P5/15, thus indicating a stronger genetic potential for stand establishment and maintenance.

Sugar yield per hectare was the result of cane yield and sucrose content in a combined manner. This study has shown some variation in sucrose content occurred among RC-1 clones, but it was narrow and in general comparable to that of POJ 2878. Therefore, the differences in sugar yield resulted mainly from differences in cane yield and not from juice quality. Clones that combined high cane yield with acceptable sucrose content—especially 19/P5/37, 19/P5/33, and 19/P5/27—had the

highest sugar yields. Inversely, clones with slight yield improvement or reduced sugar content did not show any clear advantages over the control. This trend aligns with previous studies, which have indicated the total sugar production per hectare is dependent on both cane yield and sucrose concentration. Although increasing biomass production is often the most effective pathway for sugar yield enhancement when quality traits are similar among genotypes (Hamida *et al.*, 2022; Mehareb *et al.*, 2022; Ganapathy and Jayakumar, 2023).

The promising results from a breeding standpoint show the polycross technique used on POJ 2878 produced genetic variability that could benefit the exploration and facilitation in selecting top RC-1 clones with better agronomic and yield performance. Clones with larger stalk size, adequate stalk population, and consistent sucrose content are strong contenders for further selection in the breeding program. On the other hand, clones that did not achieve higher yields in both cane and sugar than the control group require their removal from the selection process in the next cycles to enhance breeding efficiency.

## CONCLUSIONS

The study on sugarcane (*S. officinarum* L.) polycross carried out with POJ 2878 shows most RC-1 clones reaped better benefits in agronomy and yield as compared with the control variety. The improvements were mainly due to the increase in stalk length and diameter, stalk weight, the number of millable canes, cane crop, and sugar crop yields per hectare. Among these, 19/P5/37, 19/P5/33, and 19/P5/27, followed by 19/P5/21, 19/P5/1, 19/P5/22, 19/P5/24, 19/P5/15, 19/P5/6, and 19/P5/19, outperformed POJ 2878 consistently in both cane and sugar yields and thus could serve as super clones with higher production potential than the control. Meanwhile, some other clones had only a slight improvement, while two clones (19/P5/25 and 19/P5/28) are still less than the control, making them non-promising for further use.

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