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IMPROVING SUGARCANE STEM LENGTH THROUGH BIPARENTAL CROSSING FOR HIGHER SUGARCANE YIELD AND SUGAR YIELD

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ABSTRACT

Sugar productivity could be increased by increasing sugarcane stem length. This study aims to produce better stem length and weight of crossed clones with higher sugar productivity than the SIL 04 clone. The study took place in Glugur of Ngenep Village, Karangploso District, Malang Regency of East Java Province, Indonesia, from October 2022 to October 2023. As many as 18 potential clones from biparental crossing (SIL 04 x (6535, PS 881 and BL)) with AS3 (21/5/..), AS 5 (21/9/..), MLG 18 (21/25/..) and 31228 (21/46/..), and one variety of SIL 04 were arranged in a Randomized Block Design with 2 replications. The results showed that clones 5/21/11 and 9/21/36 produced stem lengths of 120.85 and 74.01%, weight of 94.99 and 34.44%, sugarcane yield of 44.98 and 39.69%, and sugar yield of 20.42, which was 26.39% higher than SIL 04 (114.22 cm, 31.33 mm, 944.21 g stem^{-1}, 82.41 t ha^{-1}, and 10.04 ha^{-1}). Improvements in sugar yield in crossed clones occurred through improvements in sugarcane yield (75.77%). Improvements in sugarcane yield occurred through improvements in stem weight (75.78%). Improvements in stem weight occurred through improvements in stem length (56.61%).

KEY WORDS

Improvement, stem length, crossing, biparental, yield, sugarcane, sugar.

Indonesia's national sugar production is still unable to meet the demand for consumption (white crystal sugar) and for industry (refined sugar), so efforts must be made to increase productivity. The limited availability of agricultural land for sugarcane has led to efforts to increase cane and sugar productivity per hectare; this can be done by using new superior varieties. Many new varieties have been generated, including SIL 04, but they have not been able to increase productivity as expected. Thus, improvements must be made to those varieties to produce new varieties with even higher and better productivity.

SIL 04 is one of the superior sugarcane varieties with a big stem diameter yet a medium-length stem (Hamida *et al.*, 2018). Stem length is one of the growth components affecting stem weight (Alam *et al*., 2017). Stem weight is one of the determining components of sugarcane yield (Side *et al.*, 2023). Sugarcane yield is one of the determining components of sugar yield (Hamida *et al.*, 2022). Thus, the effort to increase stem length is expected to increase sugarcane yield and sugar yield.

Polycross crossing of SIL 04 as the female parent with clones 6535, PS 881, and BL was carried out in 2019 and produced clones with stem lengths 1.51% shorter than SIL 04 (Yulaikah *et al*., 2023). On the other hand, clones AS3, AS5, MLG 18, and 31228 are superior clones with longer stem lengths than SIL 04 (Hamida *et al*., 2018). The superior nature of stem length, if collected into clones resulting from polycross crosses through biparental crosses, is expected to be able to produce new clones with higher sugarcane yield and sugar yield than SIL 04.

Biparental crosses between (SIL 04 x (6535, PS 881 and BL)) as the female parents with AS 3, AS 5, MLG 18, or 31228 as the male parents were carried out in 2021, and 161 numbers were obtained. The 2022 individual selection produced 18 potential clones, and a further selection stage needs to be carried out. Therefore, the study aims to obtain clones with higher stem length and weight, ultimately leading to better sugarcane yield and sugar yield than SIL 04.

MATERIALS AND METHODS OF RESEARCH

The experiment was conducted in Glugur, Ngenep Village, Karangploso District, Malang Regency of East Java Province, Indonesia, from October 2022 to October 2023. Figure 1 presents the rainfall data during the study.

The research materials used were bud chips from 18 potential clones resulting from biparental cross-selection and one SIL 04 variety as a comparison (Table 1), inorganic fertilizers, organic fertilizers, herbicides, pesticides, form A and form B chemicals, and other auxiliary materials. The tools used include tractors, hoes, sprayers, calipers, hand refractometers, sugarcane presses, saccharometers, tape measures, and other auxiliary tools.

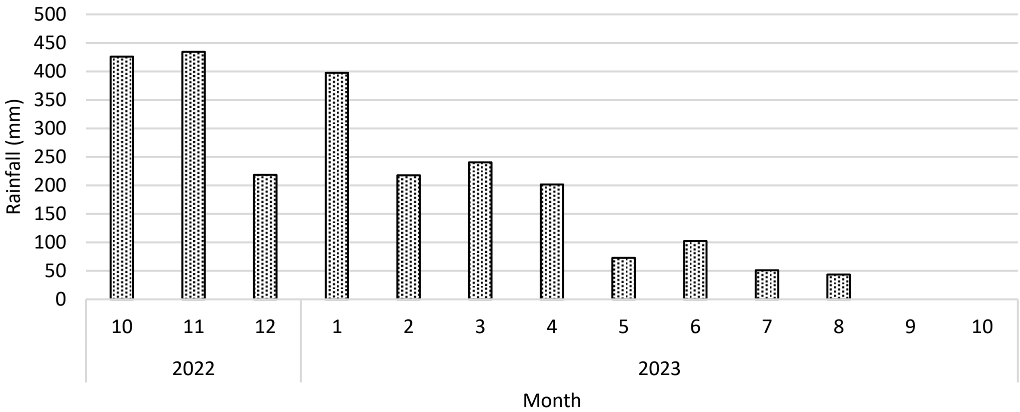

Figure 1 – Rainfall during the Study

Potential clones resulting from biparental crosses were arranged in a Randomized Block Design with 2 replications. Each clone or variety in 1 replication consisted of 2 rows with a length of 5 m. The center-to-center (CTC) distance was 110 cm, so the length of the row per hectare (the row factor) was 8100.

The distance between plants in a row was 50 cm, so each row could hold 10 plants. Before planting, organic fertilizer was applied to all the holes in the rows in a 10 tons/ha dose. Plant maintenance includes replanting, fertilizing, weeding, hilling, repairing canals, irrigation, leaf stripping, and pest and disease control. Replanting was done 2 weeks after planting by replacing dead plants with new ones until the plant population turned normal. The plants used in replanting were of the same variety as the dead plants.

Fertilization was done twice when the plants were 3-4 weeks and 3-4 months after planting. Fertilization was done in an array about 10 cm from the base of the plant stem. The dose of fertilizer given was 600 kg of Phonska and 500 kg of ZA per hectare. Phonska fertilizer was given on fertilization I, and ZA fertilizer on fertilization II.

Hilling was done 3 times by piling soil up around the plant base. Hilling I and II were done after fertilization, while Hilling III was done when the plants were 5-6 months after planting. Irrigation was done when the plants experienced temporary wilting. The pest control was carried out according to the level of pest attacks. Leaf stripping was carried out based on plant conditions by manually removing the dry leaves. Harvesting was done when the plants were 12 months after planting by pruning the plants right at the stem base. The shoots of the harvested stems were trimmed and cleaned of dry leaves. The clean stems were collected and weighed according to the plot number.

Plant growth (stem length and diameter), sugarcane components (stem weight and the number of stems per hectare), and sugar yield and production components (sucrose content and cane yield) were measured at harvest. The plants were harvested when they were 12 months old (October 2023) by cutting all the stems. Harvested stems were cleaned of leaf sheaths and shoots.

The number of stems and sugarcane yield per hectare (NM and TC) were measured by calculating the total harvested stems per plot (NP), which were then weighed to get the stem weight per plot (SWP). NM and TC are calculated using the following formulas:

$$NM = \frac{NP \times 8100}{2 \times 5} \ldots (\text{stem ha}^{-1})$$

$$TC = \frac{SWP \times 8100}{2 \times 5} \ldots\ldots.. (\text{t ha}^{-1})$$

Note: 8100 is the row factor, 2 is the number of rows, and 5 is the length of harvested rows.

Stem length, diameter, and weight were measured using 10 harvested samples per row. All sample stems were measured for length and diameter, and the stem weight was measured by weighing all the samples.

Sucrose content was measured by taking 10 sample stems to be squeezed using a press machine, and the juice was taken. The ratio of the sap weight to the weight of the squeezed stem is called the extraction factor (FP). The sap obtained was then measured for the Brix value using a hand refractometer and the pol value using a saccharometer. The amount of sap (JV), sucrose content (SC), and sugar (TSH) values are calculated using the formula:

$$JV = Pol – (0.4 \times (Brix – Pol))$$
$$SC = FP \times JV \ldots\ldots\ldots\ldots\ldots\ldots. (\%)$$
$$TS = TC \times SC \ldots\ldots\ldots\ldots\ldots(\text{t ha}^{-1})$$

The data obtained were analyzed for variance using MSTAT software version 4.00/EM. If differences are found between the clones tested, then a difference test between clones is carried out using DMRT at a level of 5%. Meanwhile, to determine the effect of stem length and diameter on stem weight, number of stems, and stem weight on sugarcane yield and sucrose content, and the effect of sugarcane yield on sugar yield, a stepwise analysis was carried out, where the correlation coefficient value obtained was multiplied by 100% and expressed as the total influence of the two variable components on stem weight, sugarcane yield, and sugar yield. A backward stepwise analysis was carried out to determine the contribution of each variable component to stem weight, cane yield, and sugar yield.

Table 1 – Clones from Crosses and Comparison Varieties Tested in the Study

No.	Clones/Varieties	Female Parents	Male Parents
1	21/5/11	SIL 04 x (6535, PS 881, BL)	AS 3
2	21/9/01	SIL 04 x (6535, PS 881, BL)	AS 5
3	21/9/05	SIL 04 x (6535, PS 881, BL)	AS 5
4	21/9/20	SIL 04 x (6535, PS 881, BL)	AS 5
5	21/9/22	SIL 04 x (6535, PS 881, BL)	AS 5
6	21/9/25	SIL 04 x (6535, PS 881, BL)	AS 5
7	21/9/30	SIL 04 x (6535, PS 881, BL)	AS 5
8	21/9/39	SIL 04 x (6535, PS 881, BL)	AS 5
9	21/9/36	SIL 04 x (6535, PS 881, BL)	AS 5
10	21/9/51	SIL 04 x (6535, PS 881, BL)	AS 5
11	21/9/54	SIL 04 x (6535, PS 881, BL)	AS 5
12	21/9/60	SIL 04 x (6535, PS 881, BL)	AS 5
13	21/25/07	SIL 04 x (6535, PS 881, BL)	MLG 18
14	21/25/08	SIL 04 x (6535, PS 881, BL)	MLG 18
15	21/46/04	SIL 04 x (6535, PS 881, BL)	31228
16	21/46/07	SIL 04 x (6535, PS 881, BL)	31228
17	21/46/10	SIL 04 x (6535, PS 881, BL)	31228
18	21/46/27	SIL 04 x (6535, PS 881, BL)	31228
19	SIL 04	-	-

RESULTS OF STUDY

Plant growth variables, which include stem length and diameter, stem weight, and number of stems, are influenced by the sugarcane clone or variety used (Tables 2 and 3). Clones 21/5/11 and 21/9/22 produced the longest stem length (243.15-252.25 cm), and clones 21/46/07 and SIL 04 produced the shortest stem length (114.22-129.17 cm). It was found that all clones tested produced stem lengths that were 23.50-120.85% longer than SIL 04, except for the clone 21/46/07, which showed no difference from SIL 04. The largest stem diameter (31.33-32.65 mm) was obtained by clones 21/9/30 and SIL 04, while the smallest (18.26 mm) was produced by 21/25/08. Compared with SIL 04, not a single clone had a larger diameter; clones 21/9/20, 21/9/30, and 21/9/39 were not different, and the other clones were 5.87-41.72% smaller than SIL 04.

Table 2 – Stem Length and Diameter of Clones Resulting from Crosses and Improvements to the SIL 04 Variety

Clones	Stem length		Stem diameter	
	(cm)	Increasing (%)	(mm)	Increasing (%)
21/5/11	252.25 a	120.85	29.49 c	-5.87
21/9/01	182.64 cde	59.90	26.07 def	-16.79
21/9/05	207.38 bc	81.56	29.36 c	-6.29
21/9/20	160.44 efg	40.47	30.96 bc	-1.18
21/9/22	243.15 a	112.88	24.68 fg	-21.23
21/9/25	141.06 gh	23.50	27.19 de	-13.21
21/9/30	189.17 bcd	65.62	32.65 a	4.21
21/9/39	144.28 gh	26.32	30.71 bc	-1.98
21/9/36	198.75 bc	74.01	27.57 d	-12.00
21/9/51	149.38 fgh	30.78	29.56 c	-5.65
21/9/54	185.63 cd	62.52	25.32 f	-19.18
21/9/60	212.14 b	85.73	25.97 of	-17.11
21/25/07	192.29 bcd	68.35	23.19 g	-25.98
21/25/08	171.50 def	50.15	18.26 i	-41.72
21/46/04	201.46 bc	76.38	20.62 h	-34.18
21/46/07	129.17 hi	13.09	19.85 h	-36.64
21/46/10	157.50 fg	37.89	23.40 g	-25.31
21/46/27	144.30 gh	26.34	19.79 h	-36.83
SIL 04	114.22 i		31.33 ab	

Note: Numbers accompanied by the same letter in one column mean they are not significantly different at the Duncan Multiple Range Test at the 5% level. The minus sign (-) in the increase (%) column means there has been a decrease in SIL 04.

The largest stem weight (1697.7-1841.1 g stem^{-1}) was produced by clones 21/5/11 and 21/9/30, while the lowest (428.2-481.9 g stem^{-1}) was produced by clones 21/25/08, 21/46/07 and 21/46/27. In comparison to SIL 04, 7 clones (21/5/11, 21/9/01, 21/9/05, 21/9/22, 21/9/30, 21/9/36, and 21/9/60) produced a higher stem weight by 27.82-94.99%, 3 clones (21/25/08, 21/46/07, and 21/46/27) produced a lower stem weight by 48.96-54.65%, and the rest showed no difference stem weight from SIL 04.

The highest number of stems (94163-102600 stem ha^{-1}) was produced by clones 21/46/07 and 21/46/27, while the lowest (39343-44337 stem ha^{-1}) was produced by clones 21/9/30, 21/9/51 and 21/46/04. In comparison to SIL 04, clone 21/46/27 produced a higher number of stems by 18.75%, 6 clones (21/9/01, 21/9/36, 21/25/07, 21/25/08, 21/46/07, and 21/46/10) showed no difference from SIL 04, and the rest produced a lower number of stems by 13.75-54.46%.

Yield variables include cane yield, sucrose content, and sugar yield—all are affected by the clones or varieties used (Table 4). The highest cane yield (100.07-119.48 t ha^{-1}) was shown by the clones 21/5/11, 21/9/05, and 21/9/36, while the lowest (32.09-49.26 t ha^{-1}) was shown by the clones 21/9/51, 21/25/08, 21/46/04, 21/46/07, and 21/46/27. In comparison to SIL 04, 2 clones (21/5/11 and 21/9/36) showed a higher yield by 39.69-44.98%, 5 clones

(21/9/51, 21/25/08, 21/46/04, 21/46/07, and 21/46/27) showed a lower yield by 40.23-61.06%, and the rest showed no difference from SIL 04.

Table 3 – Weight and Number of Stems of Clones Resulting from Crosses and Improvements to the SIL 04 Variety

Clones	Stem weight		Number of Millable Cane	
	(g stem^{-1})	Increasing (%)	(stem ha^{-1})	Increasing (%)
21/5/11	1841.1 a	94.99	64800 hi	-25.00
21/9/01	1043.3 cdef	10.50	76950 efg	-10.94
21/9/05	1517.5 b	60.72	64800 hi	-25.00
21/9/20	1291.9 c	36.82	64800 hi	-25.00
21/9/22	1246.4 cd	32.01	67838 ghi	-21.48
21/9/25	875.8 fg	-7.24	68040 ghi	-21.25
21/9/30	1697.7 ab	79.80	39343 j	-54.46
21/9/39	1144.3 cde	21.19	63327 i	-26.70
21/9/36	1269.4 c	34.44	90379 bc	4.61
21/9/51	1106.0 cdef	17.14	43200 j	-50.00
21/9/54	1011.9 def	7.17	74520 fgh	-13.75
21/9/60	1206.9 cd	27.82	64800 hi	-25.00
21/25/07	868.7 fg	-8.00	83314 cdef	-3.57
21/25/08	481.9 h	-48.96	79591 def	-7.88
21/46/04	719.9 g	-23.76	44337 j	-48.68
21/46/07	428.2 h	-54.65	94163 ab	8.98
21/46/10	724.8 g	-23.24	88200 bcd	2.08
21/46/27	475.7 h	-49.62	102600 a	18.75
SIL 04	944.2 efg		86400 bcde	

Note: Numbers accompanied by the same letter in one column mean they are not significantly different at the Duncan Multiple Range Test at the 5% level. The minus sign (-) in the increase (%) column means there has been a decrease in SIL 04.

Table 4 – Cane Yield, Sucrose Content, and Sugar Yield of Clones Resulting from Crosses and Improvements to the SIL 04 Variety

Clones	Cane yield		Sucrose content		Sugar yield	
	(t ha^{-1})	Increasing (%)	(%)	Increasing (%)	(t ha^{-1})	Increasing (%)
21/5/11	119.48 a	44.98	10.06 gh	-19.46	12.09 a	20.42
21/9/01	80.55 bcd	-2.26	10.89 def	-12.81	8.82 cdef	-12.15
21/9/05	100.07 ab	21.43	11.13 cdef	-10.89	11.26 ab	12.15
21/9/20	83.82 b-d	1.71	10.77 ef	-13.77	9.04 bcde	-9.96
21/9/22	85.26 bc	3.46	11.54 bcd	-7.61	9.87 bcde	-1.69
21/9/25	60.02 defg	-27.17	11.42 bcde	-8.57	6.89 efghi	-31.37
21/9/30	67.32 def	-18.31	11.07 def	-11.37	7.47 defgh	-25.60
21/9/39	72.85 cde	-11.60	11.37 bcde	-8.97	8.28 cdefg	-17.53
21/9/36	115.12 a	39.69	11.01 def	-11.85	12.69 a	26.39
21/9/51	48.57 fgh	-41.06	11.96 ab	-4.24	5.82 fghij	-42.03
21/9/54	76.86 bcd	-6.73	11.19 cdef	-10.41	8.66 cdef	-13.75
21/9/60	79.17 bcd	-3.93	10.00 h	-19.94	8.01 defg	-20.22
21/25/07	72.80 cde	-11.66	11.72 bc	-6.16	8.55 cdefg	-14.84
21/25/08	38.70 gh	-53.04	9.94 h	-20.42	3.85 ij	-61.65
21/46/04	32.09 h	-61.06	10.65 fg	-14.73	3.44 j	-65.74
21/46/07	40.78 gh	-50.52	10.65 fg	-14.73	4.36 hij	-56.57
21/46/10	64.25 cdef	-22.04	10.89 def	-12.81	7.03 efgh	-29.98
21/46/27	49.26 efgh	-40.23	10.89 def	-12.81	5.39 fghij	-46.31
SIL 04	82.41 bcd		12.49 a		10.04 bcd	

Note: Numbers accompanied by the same letter in one column mean they are not significantly different at the Duncan Multiple Range Test at the 5% level. The minus sign (-) in the increase (%) column means there has been a decrease in SIL 04.

The highest sucrose content (11.96-12.49%) was produced by clones 21/9/51 and SIL 04, while the lowest (9-94-10.06%) was obtained by clones 21/5/11, 21/9/60, and 21/25/08. No clones had a bigger stem diameter than SIL 04 (the clone 21/9/51 showed no difference in stem diameter to SIL 04, while other clones showed a smaller stem diameter by 6.16-20.42%. The biggest sugar yield (11.26-12.69 t ha^{-1}) was produced by 21/5/11, 21/9/05, and

21/9/36, while the lowest (3.44-5.82 t ha^{-1}) was produced by 21/9/51, 21/25/08, 21/46/04, 21/46/07, and 21/46/27. In comparison to SIL 04, 2 clones (21/5/11 and 21/9/36) showed a higher sugar yield by 20.42-26.39%, 6 clones (21/9/25, 21/9/51, 21/25/08, 21/46/04, 21/46/07, and 21/46/27) showed a lower sugar yield by 31.37-65.74%, and the rest showed no difference from SIL 04.

DISCUSSION OF RESULTS

Sugarcane stem growth, both longitudinal growth (stem length) and width (stem diameter), is influenced by the availability of carbohydrates for stem growth (Djumali *et al*., 2018). The availability of carbohydrates is determined by the amount of carbohydrate partitioning for the growth of sugarcane plant organs and the rate of plant photosynthesis as a source of carbohydrate production (Liu *et al*., 2020). Under homogeneous growing environmental conditions, the amount of carbohydrate partitioning and the rate of plant photosynthesis are influenced by the clone or variety used (Diana *et al*., 2020). Likewise, carbohydrate partitioning for growth in stem length and width is influenced by the clone or variety used (Wang *et al*., 2013). Therefore, the length and diameter of the sugarcane stem are influenced by the clone or variety used. The research results of Schultz *et al.* (2017) show that differences in sugarcane clones result in differences in stem length. Likewise, Palachai *et al.* (2021) show that differences in sugarcane clones result in differences in stem diameter.

The obtained stem weight of sugarcane is determined by the growth components, namely the length and diameter of the stem (Kumar *et al*., 2023). In this research, the relationship between stem weight (SW), stem length (SL), and stem diameter (SD) could be written in the following equation of SW = 0.7947 SL + 1.3274 SD - 1.0054, with a correlation value (r) of 0.986. This result means that stem length and diameter positively affect stem weight, with a total effect size of 98.6%. The backward stepwise analysis showed that stem length affected stem weight by 56.61%, while stem diameter affected stem weight by 41.99%. Thus, stem weight is more influenced by stem length than stem diameter. These results mean that improvements in stem weight are more likely to occur through improvements in stem length. Considering that clones 5/21/11 and 9/21/36 produced quite long stem lengths (Table 2), these two clones also produced quite large stem weights (Table 3). Supriyono *et al.* (2023) show that stem length has a greater influence on stem weight than stem diameter. Ahmed (2017) shows the influence of the clone or variety used on obtained stem weight.

Harvested stems are the part of the sugarcane tillers that receive sufficient carbohydrates to support their growth. Tillers not getting sufficient growth carbohydrates will die, so the number of stems harvested is less than the number of tillers formed. The amount of carbohydrates available depends on the plant's photosynthesis rate. The number of tillers formed and the plant photosynthesis rate are influenced by the clone or variety (Chohan *et al*., 2014; Leanasawat *et al*., 2021). Therefore, the number of harvested stems is influenced by the clone or variety. Begum *et al.* (2017) show the influence of sugarcane clones or varieties on the number of harvested stems.

Stem weight per stem and number of harvested stems are two growth variables that influence sugarcane yield (Urgesa and Kiyata, 2021). In this research, the relationship between sugar cane yield (CY), stem weight (SW), and number of stems (NMC) could be written in the following equation of CY = 0.98058 SW + 0.79854 NMC – 0.51688, with a correlation coefficient (r) of 0.963. This means that the weight and number of stems positively affected sugarcane yield, with a total effect of 96.3%. The backward stepwise analysis shows that stem weight affected sugarcane yield by 75.78%, and the number of stems affected sugarcane yield by 20.52%. Thus, stem weight influences sugarcane yields more than the number of stems. This means that improvements in sugarcane yield occurred through improvements in stem weight. Shikanda *et al.* (2017), who used 22 introduced sugarcane clones, show that stem weight and number of stems influence sugarcane yield. Side *et al.* (2023), who used radiation-produced mutant sugarcane clones, show that stem weight is more dominant (50.82%) in influencing sugarcane yield than the number of stems. Because stem weight is influenced by clone or variety interactions, sugarcane yield is also influenced by clone or variety (Sarwar *et al*., 2019). Moraes *et al.* (2018) show that sugarcane yield is influenced by the clone used.

Sucrose content reflects the amount of sucrose in the stem, so the amount of sucrose and stem weight determines the sucrose content. The sucrose in the stem results from accumulated stored carbohydrates produced in photosynthesis during the ripening phase. Stem weight, photosynthesis rate, and the ripening phase of sugarcane plants are influenced by the clone or variety used. Therefore, sucrose content is influenced by the sugarcane clone or variety. Ahmad *et al.* (2022), Zhao *et al.* (2022), and Anjos *et al.* (2023) show an influence of clone or variety on the resulting sucrose content.

Sugar yield is the accumulated weight of sugar in all harvested sugarcane stems. The sugar yield is a function of cane yield and sucrose content. Therefore, sugarcane yield and sucrose content influence sugar yield (Hamida *et al*., 2022). In this research, the relationship between sugar yield and cane yield (CY) with sucrose content (SC) can be written in the following equation of SY = 0.97945 CY + 0.57070 SC – 0.51039, with a correlation coefficient (r) of 0.999. The results of this equation mean that sugarcane yield and sucrose content have a positive effect on sugar yield, with a total influence value of 99.9%. The backward stepwise analysis confirmed that the contribution of sugarcane yield to sugar yield was 75.77%, and sucrose content to sugar yield was 24.13%. These results show that improvements in sugar yield occurred through improvements in sugarcane yield. Since clones 5/21/11 and 9/21/36 obtained the largest sugarcane yields, these two clones also obtained the largest sugar yields (Table 4). Side *et al.* (2023) show a dominance of sugarcane yield in influencing sugar yield. Considering that sugarcane yield and sucrose content are influenced by the clone or variety, the sugar yield is also influenced by the clone or variety used (Riajaya *et al*., 2022a). Likewise, Zhao and Li (2015), Jamoza *et al.* (2019), and Riajaya *et al.* (2022b) show that sugar yield was influenced by the clone or variety used.

CONCLUSION

Clones 5/21/11 and 9/21/36 produced stem lengths of 120.85 and 74.01%, stem weight of 94.99 and 34.44%, sugarcane yield of 44.98 and 39.69%, and sugar yield of 20.42 and 26.39%, all were higher than the SIL 04 variety (114.22 cm, 31.33 mm, 944.21 g stem^{-1}, 82.41 t ha^{-1}, and 10.04 ha^{-1}). The sugar yield improvement occurred through sugarcane yield improvement (75.77%). The sugarcane yield improvement occurred through stem weight improvement (75.78%). The stem weight improvement occurred through stem length improvement (56.61%).

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