RJOAS: Russian Journal of Agricultural and Socio-Economic Sciences
ISSN 2226-1184 (Online) | Issue 11(155), November 2024

UDC 633

IMPROVING GROWTH AND PRODUCTIVITY OF POJ 2878 THROUGH BIPARENTAL CROSSING

Murianingrum Mala, **Machfud M.***, **Djumali**, **Herwati Anik**, **Purwati Rully Dyah**, **Heliyanto Bambang**, **Supriyono**, **Suhara Cece**
Research Center for Estate Crops, Research Organization for Agriculture and Food,
The National Research and Innovation Agency, Bogor, West Java, Indonesia
*E-mail: moch060@brin.go.id

ABSTRACT
The increase in sugar demand over the last 5 years has led to efforts to increase sugar production, including creating new superior varieties; the biparental crossing is one way to produce new superior varieties. The study was done at IP2TP Karangploso, Malang, Indonesia, from December 2020 to November 2022; it aims to obtain potential clones that produce higher crystals than female parents. Seventeen clones resulting from crosses and one female parent (POJ 2878) were arranged in a Randomized Block Design with 2 repetitions. The results showed that apart from clone 19/18/10, all clones tested produced sugar yield at 5.94-10.88 t/ha, which increased 72.87% from the female parent (4.93 t/ha). Of the clones that experienced an increase, 9 clones (19/3/2, 19/3/4, 19/3/5, 19/3/8, 19/3/11, 19/3/14, 19/ 3/15, 3/19/16, and 3/19/19) showed an increase in sugar yield by 74.83-120.57%, or more than 72.87% of the female parents. The increase in sugar yield occurs through increased sugarcane productivity.

KEY WORDS
Sugarcane, sugar yield, clones, new superior varieties, stem length, stem diameter.

Indonesia’s sugar demand over the last five years was 5.16 million tons per year, with 3.2 tons of white crystal sugar and the rest refined sugar (BPS, 2021). The average sugarcane development area is 423,157 ha, with sugar productivity (sugar yield) of 5.16 t/ha, so national sugar production is only 2.18 million tons annually (Ditjenbun, 2020). One effort to increase sugar productivity is the creation of new superior varieties with high productivity.

Creating new superior varieties can be done through biparental crossing. POJ 2878 is a superior sugarcane variety produced from a genetic jump due to a cross between a novel sugarcane cultivar and the wild species *S. spontaneum*. The offspring were backcrossed with *S. officinarum*. This variety is used as a female parent in sugarcane crosses almost everywhere. MLG 14 is a potential clone with high sucrose content in high-moisture soil conditions, while clone 3179 is a potential clone with high productivity (Hamida et al., 2018). Meanwhile, Cening is a superior variety with high sucrose content in high-moisture soil conditions (Ministry of Agriculture, 2010). Using these three clones or varieties as male parents in biparental crosses are expected to produce new superior varieties with higher sugar yield than the female parents.

The biparental crossing was carried out in 2019, producing 49 new clones (Heliyanto et al., 2019). The selection of the clones from the cross resulted in 17 clones producing sugar yields higher than the average (Heliyanto et al., 2020). Further selection is necessary with a benchmark of higher crystal sugar yields from female parents. Therefore, research was conducted to obtain clones that produced higher sugar yields than their female parents.

MATERIALS AND METHODS OF RESEARCH

The study was done at IP2TP Karangploso, Malang, Indonesia, from December 2020 to November 2022. Table 1 presents the soil fertility levels, while Figure 1 depicts the rainfall during the study. The research materials used were bud chips from 17 potential clones resulting from biparental cross-selection (POJ 2878 x MLG 14, 3170, and Cening) and one female parent as a comparison (Table 2). Those 17 clones resulted from the 2020 selection and 2019 crosses. Other materials were NPK compound fertilizer, manure, and other chemicals. The tools used included meters, scales, calipers, refractometers and other auxiliary tools.

The clones from the cross and one comparison variety (POJ 2878) were arranged in a Randomized Block Design with 2 replications. Each clone or variety in one replication consisted of one row with a length of 10 m. The center-to-center (CTC) distance was 110 cm, so the length of the row per hectare (the row factor) was 8100.

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.

For plant cane (PC), fertilization was done twice when the plants were 3-4 weeks and 3-4 months after planting, while for ratoon cane (RC), fertilization was done 1 and 3 months after stump cutting. 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 was given on fertilization II. Hilling was done 3 times by piling soil up around the plant base in a row. Hilling I and II were done after fertilization, while Hilling III was done when the plants were 5-6 months after planting or stem cutting. 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 or stem cutting 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.

Observations were made before and during harvest. The number of stems per meter of row (JBM) was counted before harvest by counting all stems (JB) with a stem length of more than 150 cm and a stem diameter of more than 2.0 cm in all rows. The number of stems per meter of row (JBM) is calculated using the formula:

$$\text{JBM} = \frac{JB}{The\ length\ of\ the\ entire\ row}$$

Observation of stem length, diameter, and weight was carried out at harvest. As many as 10 harvested stems were taken per plot as sample plants. Each sample plant was observed for length and diameter. The stem diameter was observed at the center of the stem. Stem weight was observed by weighing all sample plants. Sucrose content was measured from sample plants that had been squeezed. The sap produced was measured by sap weight, Brix and pol values.

The extracting factor (FP) is calculated using the formula:

$$\text{FP} = \frac{Sap\ weight}{Stem\ weight}$$

The sap value is calculated using the formula:

$$\text{NN} = 0.4 \times (\text{brix} - \text{pol})$$

The sucrose content is calculated using the formula:

$$\text{Sucrose content (\%)} = \text{FP} \times \text{NN}$$

Cane productivity (Protas) and sugar yield (Hablur) are measured using the formulas:

$$\text{Protas (t/ha)} = 8100 \times \frac{stem\ weight\ per\ plot}{total\ length\ of\ plot}$$

$$\text{Hablur (t/ha)} = \text{Protas} \times \text{Sucrose Content}$$

Table 1 – Chemical properties of experimental soil in IP2TP Karangploso, Malang, Indonesia

Soil chemical properties	Value	Categories*)
pH 1:1		
• H_2O	5.6	Acid
• KCl 1N	5.3	
C Organic (%)	1.56	Very low
N total (%)	0.14	Low
C/N	11.0	Low
P_2O_5 Bray (mg.kg^{-1})	3.05	Low
K NH_4OAC1N pH:7 (me/100g)	0.12	Low
Na NH_4OAC1N pH:7 (me/100g)	0.90	Low
Ca NH_4OAC1N pH:7 (me/100g)	15.04	Medium
Mg NH_4OAC1N pH:7 (me/100g)	0.54	Medium
KTK NH_4OAC1N pH:7 (me/100g)	30.60	Medium
Total bases (me/100g)	16.60	Low
Base saturation	54	Medium
Texture:		Silty clay
• Sand (%)	6	
• Silt (%)	45	
• Clay (%)	49	

**) Source: Sulaeman et al. (2012).*

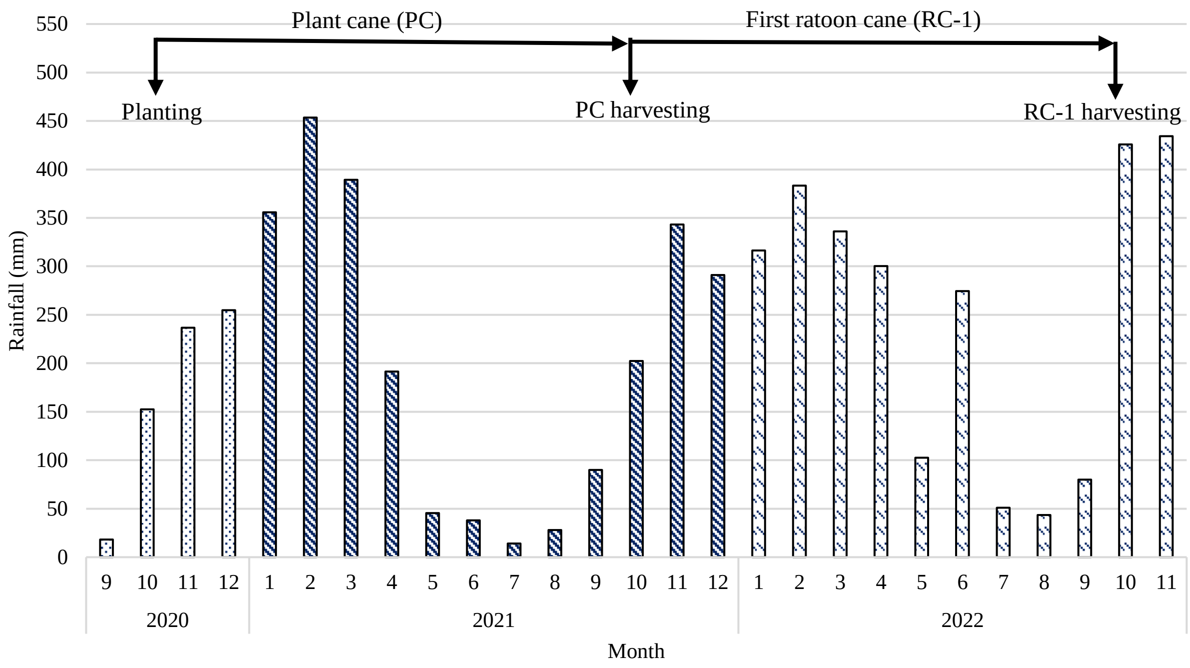

Figure 1 – Rainfall at IP2TP Karangploso, Malang, Indonesia during the study

Table 2 – Clones used in the experiment

No.	Clones	No.	Clones	No.	Clones
1.	19/3/2	7.	19/3/10	13.	19/3/19
2.	19/3/4	8.	19/3/11	14.	19/18/7
3.	19/3/5	9.	19/3/13	15.	19/18/10
4.	19/3/6	10.	19/3/14	16.	19/18/24
5.	19/3/7	11.	19/3/15	17.	19/26/2
6.	19/3/8	12.	19/3/16	18.	POJ 2878

The data obtained were analyzed by combined variance and followed by Duncan's multiple range test (DMRT) at the 5% level using MSTAT software version 4.00/EM. Backward stepwise analysis was used to determine the magnitude of each component's influence on stem weight, sugarcane productivity, and crystal sugar yield.

RESULTS AND DISCUSSION

Sugarcane plant growth, which includes stem length and diameter, is influenced by the interaction between sugarcane clones and sugarcane growth status (Table 3). Previous sugarcane research results also show that the length and diameter of sugarcane stems are influenced by the sugarcane clones used (Abu-Ellail et al., 2020; Ali et al., 2021; Supriyono et al., 2023). In PC sugarcane, clones 19/3/10 and 19/3/14 produced the longest stem lengths (236.54-242.92 cm) and the shortest (144.88-149.15 cm) happened to clones 19/18/7 and 19/18/24. The longest stems (237.71-252.81 cm) on RC cane were obtained by 19/3/7, 19/3/8, 19/3/10, 19/3/11, and 19/3/15 clones and the shortest (168.02-172.29 cm) by 19/18/7, 19/18/24, 19/26/2 and POJ 2878 clones. In comparison to the female parent, results showed that 9 clones (19/3/2, 19/3/4, 19/3/7, 3/19/8, 3/19/10, 3/19/13, 3/19/14, 3/19/15, and 3/19/19) for PC and 13 clones (3/19/2, 19 3/4, 3/19/5, 3/19/6, 3/19/7, 3/19/8, 3/19/10, 3/19/11, 3/19/13, 3/19 /14, 19/3/15, 19/3/16, and 19/3/19) for RC produced longer stem length than the female parent. From the average of each clone, there was an increase in stem length of 16.98% from the female parent. The clones that produced an increase in stem length of more than 16.98% were 19/3/2, 19/3/4, 19/3/6, 19/3/7, 19/3/8, 19/3/10, 19 /3/11, 3/19/13, 3/19/14, 3/19/15, and 3/19/19. Mohammed et al. (2019) also showed that clones from crosses produced shorter and longer stem lengths than their parents.

Table 3 – Stem length and diameter of cross-bred sugarcane clones and their female parent in PC and RC and their averages

Clones	Stem length (cm)			Stem diameter (mm)		
	PC	RC	Average	PC	RC	Average
19/3/2	213.19 g-k	232.50 b-f	222.84 CD	29.78 bc	25.74 g-j	27.76 B
19/3/4	220.83 e-j	202.50 j-l	211.67 D-F	30.84 ab	27.86 de	29.35 A
19/3/5	206.58 i-l	205.31 i-l	205.94 EF	32.21 a	27.80 d-f	30.01 A
19/3/6	195.65 kl	228.88 b-g	212.26 D-F	28.28 cd	25.96 g-i	27.12 BC
19/3/7	226.96 c-h	243.54 a-c	235.25 B	26.31 e-h	25.01 h-k	25.66 D-G
19/3/8	232.40 b-f	245.71 ab	239.05 AB	28.70 cd	24.82 h-l	26.76 B-D
19/3/10	242.92 a-c	252.81 a	247.86 A	28.96 cd	25.03 h-k	26.99 BC
19/3/11	195.19 kl	237.71 a-e	216.45 C-E	23.03 l-n	24.15 i-m	23.59 J
19/3/13	216.58 f-j	221.67 d-i	219.13 CD	25.73 g-j	23.18 k-n	24.46 G-J
19/3/14	236.54 a-e	220.28 e-j	228.41 BC	25.69 g-j	21.86 n	23.78 IJ
19/3/15	230.35 b-g	239.83 a-d	235.09 B	23.09 l-n	24.17 i-m	23.63 J
19/3/16	207.63 i-l	195.54 kl	201.58 F	26.11 e-h	25.85 g-i	25.98 C-F
19/3/19	213.54 g-k	209.75 h-k	211.65 D-F	24.80 h-l	27.30 d-g	26.05 C-F
19/18/7	144.88 o	172.29 n	158.59 H	25.45 g-j	23.37 k-n	24.41 H-J
19/18/10	176.88 mn	177.81 mn	177.34 G	26.01 f-i	26.26 e-h	26.13 C-F
19/18/24	149.15 o	171.15 n	160.15 H	27.23 d-g	23.45 k-n	25.34 E-H
19/26/2	195.26 kl	169.32 n	182.29 G	23.91 j-m	25.93 g-i	24.92 F-I
POJ 2878	190.56 lm	168.02 n	179.29 G	29.83 bc	22.62 mn	26.22 C-E
Average	205.28 Y	210.81 X		27.00 X	25.02 Y	

Note: Numbers followed by the same letters show no significant difference in the Duncan 5% test.

The biggest stem diameter (30.84-32.21 mm) in PC was obtained by clones 19/3/4 and 19/3/5, while the smallest (23.03-23.91 mm) was obtained by clones 19/3/11, 19/3/15, and 19/26/ 2. As for RC, the biggest stem diameter (27.30-27.86 mm) was obtained by clones 19/3/4, 19/3/5, and 19/3/19, and the smallest (21.86-23.45 mm) was obtained by clones19/3/13, 19/3 /14, 19/18/2, and POJ 2878. In comparison to the female parent, results showed that only clone in PC 19/3/5 obtained a bigger stem diameter and 11 clones in RC (19/3/2, 19/3/4, 3/19/5, 3/19/6, 3/19/7, 3/19/8, 3/19/10, 3/19/16, 3/19/19, 18/19/10, and 19 /26/2). From the average of each clone, there was a decrease in stem diameter of 0.86% from the female parent (26.22 mm). However, 3 clones (19/3/2, 19/3/4, and 19/3/5) showed an increase in stem diameter of 5.46-18.44% from the female parent. Hamida et al. (2022) also showed that clones from crosses produced smaller and bigger stem diameters than their parents.

Sugarcane production components included weight per stem and number of stems per hectare; they are influenced by the interaction between sugarcane clones and sugarcane planting status (Table 4). Palachai et al. (2019) and Rakesh et al. (2020) also showed the influence of sugarcane clones on sugarcane weight and number of harvested stems. The highest weight of cane stems for PC (1,779-1,807 kg/stem) was obtained by clones 19/3/4 and 19/3/5, and the lowest (0.793-0.893 kg/stem) was obtained by clones 19/3/11 and 19/18/7. As for RC, the highest stem weight (1,275-1,334 kg/stem) was obtained by clones 19/3/2, 19/3/4, 19/3/5, 19/3/6, 19/3/7, 19/3/8, 19/3/10, and 19/3/19, while the lowest (0.723-0.796 kg/stick) was obtained 19/18/7, 19/18/24, and POJ 2878. In comparison to the female parent, results showed that 4 clones in PC (19/3/4, 19/3/5, 19/3/8, and 19/3/10) and 15 clones in RC (19/3/2, 19/3/ 4, 3/19/5, 3/19/6, 3/19/7, 3/19/8, 3/19/10, 3/19/11, 3/19/13, 3/19/14/ 3/19/15, 3/19/16, 3/19/19, 18/19/10 and 2/19/26) produced higher stem weights than the female parent. From the average for each clone, there was an increase in stem weight of 9.95% from the female parent (1,092 kg/stem). The clones that produced higher stem weights than the female parent was 19/3/2, 19/3/4, 19/3/5, 19/3/6, 19/3/7, 19/3/8, 19 /3/10, 19/3/16, and 19/3/19). Of the 9 clones, only 19/3/16 produced an increase in stem weight of less than 9.95%, at 9.68%. Getaneh et al. (2015) and Biradar et al. (2016) also showed that clones from crosses produced higher stem weights, yet some produced no different weight from their parents.

Stem length and diameter are two components that influence stem weight (Jun-Luo et al., 2014). In this research, the relationship between stem weight (SW) and length (SL) and stem diameter (SD) formed the equation SW = 0.7583 SL + 1.6278 SD – 1.2772, with a correlation coefficient of 0.991; this means that the total influence of stem length and diameter on stem weight is 99.1%. Mahadevaiah et al. (2021) and Murianingrum et al. (2020) also showed a positive correlation between stem weight and stem length and diameter. The total influence of 99.1% is composed of the influence of SL of 28.9% and SD of 70.2%. From the magnitude of each of these effects, it can be concluded that improvements in stem weight mostly occur through increased stem diameter. Yulaikah et al. (2023) also showed that the effect of stem diameter on stem weight was greater than the effect of stem length.

Table 4 – Stem weight and number of stems per hectare of cross-bred sugarcane clones and their female parent in PC and RC and their averages

Clones	Stem weight (kg stem^{-1})			Number of millable canes per ha		
	PC	RC	Average	PC	RC	Average
19/3/2	1.530 cd	1.316 ef	1.423 C	78141 g-k	98589 bc	88365 C
19/3/4	1.779 a	1.321 ef	1.550 AB	59738 n-p	95175 b-d	77456 EF
19/3/5	1.807 a	1.334 e	1.571 A	74520 h-l	86063 d-h	80291 C-E
19/3/6	1.304 ef	1.299 e-g	1.302 D	66046 k-p	74520 h-l	70283 FG
19/3/7	1.237 e-i	1.279 e-h	1.258 DE	65610 k-p	82851 d-i	74231 EF
19/3/8	1.615 bc	1.275 e-h	1.445 C	72900 i-m	99630 bc	86265 CD
19/3/10	1.649 b	1.330 ef	1.490 BC	67659 j-o	81926 e-i	74792 EF
19/3/11	0.893 qr	1.162 h-k	1.028 HI	91414 c-f	120343 a	105879 A
19/3/13	1.210 f-j	1.011 m-p	1.111 G	66825 j-p	60750 m-p	63788 GH
19/3/14	1.290 e-g	0.889 qr	1.089 GH	88674 c-g	104130 b	96402 B
19/3/15	1.080 k-n	1.180 g-k	1.130 FG	99000 bc	93600 b-e	96300 B
19/3/16	1.296 e-g	1.099 j-m	1.198 EF	71621 i-n	87120 c-h	79371 DE
19/3/19	1.130 i-l	1.314 ef	1.222 E	79295 f-j	85770 d-h	82532 C-E
19/18/7	0.793 rs	0.796 rs	0.795 K	91125 c-f	82620 d-i	86873 CD
19/18/10	0.978 n-q	1.033 l-o	1.005 IJ	55890 op	59535 n-p	57713 HI
19/18/24	0.912 pq	0.792 rs	0.852 K	75032 h-l	63630 l-p	69331 FG
19/26/2	0.932 o-q	0.957 o-q	0.945 J	72424 i-l	77181 g-k	74802 EF
POJ 2878	1.461 d	0.723 s	1.092 GH	54900 p	55080 op	54990 I
Average	1.272 X	1.117 Y		73934 Y	83806 X	

Note: Numbers followed by the same letters show no significant difference in the Duncan 5% test.

The highest number of stems per hectare of PC (88674-99000 stems/ha) was produced by clones 19/3/11, 19/3/14, 19/3/15, and 19/18/7, while the lowest (54900-66046 stems/ha) was produced by clones 3/19/4, 3/19/6, 3/19/7, 3/19/13, and 18/19/10. As for RC, the highest number of stems (120343 stems/ha) was produced by 19/18/11, while the lowest (55080-63630 stems/ha) was produced by clones 19/3/13, 19/18/10, 19/18/24, and POJ 2878. In comparison to the female parents, the clones tested (except 19/3/4, 19/3/6, 19/3/7, 19/3/13, and 19/18/10) produced a higher number of stems than the female parent in PC, whereas for RC, all clones produced a greater number of stems except 19/3/13, 19/18/10, and 19/18/24. From the average for each clone, there was an increase in the number of stems by 45.98% from the female parent (54990 stems/ha). Apart from clone 19/18/10, all clones tested produced a higher number of stems per hectare (63788-105879 stems/ha) than the female parent (54990 stems/ha).

Sugarcane productivity, sucrose content, and sugar yield are influenced by the interaction between sugarcane clones and sugarcane planting status (Tables 5 and 6). The research results of Naidu et al. (2017), Sarol et al. (2020), and Mahmood-Ul-Hassan et al. (2020) show that sugarcane productivity, sucrose content, and crystal sugar yield are influenced by the clones used. The highest sugarcane productivity (88.67-99.00 t/ha) in PC sugarcane was produced by clones 19/3/11, 19/3/14, 19/3/15, and 19/8/7, while the lowest (54.90-66.05 t/ha) was produced by clones 19/3/4, 19/3/6, 19/3/7, 19/3/13, 19/18/10, and POJ 2878. As for RC, the highest sugarcane productivity (140.40 t/ha) was produced by 19/3/13, and the lowest (39.37 t/ha) was produced by POJ 2878. In comparison to the female parent, all clones in PC, except 19/3/4, 19/3/6, 19/3/7, 19/3/13, and 19/18/10, produced higher sugarcane productivity than the female parent, while all clones in RC produced higher sugarcane productivity than the female parent. From the average of each clone, there was an increase in sugarcane productivity of 83.39% from the female parent (47.38 t/ha). All clones tested produced higher sugarcane productivity (58.75-115.91 t/ha) than the female parent. The clones that resulted in an increase in sugarcane productivity of more than 83.39% were 3/19/2, 3/19/4, 3/19/5, 3/19/8, 3/19/10, 3/19/11, 19/3/14, 3/19/15, and 3/19/19 (86.50-120.58%). Bhavana et al. (2017a) and Sarwar et al. (2019) showed that clones from crosses produced lower and higher sugarcane productivity than the comparison varieties.

Table 5 – Sugarcane productivity and sucrose content of cross-bred sugarcane clones and their female parent in PC and RC and their averages

Clones	Tons of cane per ha (t ha^{-1})			Sucrose content (%)		
	PC	RC	Average	PC	RC	Average
19/3/2	78.14 h-j	129.70 b	103.92 BC	10.06 d-h	10.70 a-e	10.38 A-C
19/3/4	59.74 l-o	125.83 bc	92.78 D-F	10.12 d-g	10.89 a-d	10.50 AB
19/3/5	74.52 ij	115.29 cd	94.91 DE	10.00 e-i	11.25 a	10.62 AB
19/3/6	66.05 j-n	96.77 fg	81.41 HI	8.64 mn	10.30 b-f	9.47 EF
19/3/7	65.61 j-n	106.24 d-f	85.93 F-I	9.23 h-n	10.06 d-h	9.64 D-F
19/3/8	72.90 i-k	128.84 b	100.87 B-D	10.00 e-i	8.75 l-n	9.38 EF
19/3/10	67.66 i-m	109.09 de	88.37 E-H	9.23 h-n	8.99 k-n	9.11 FG
19/3/11	91.41 g	140.40 a	115.91 A	8.70 l-n	8.52 n	8.61 G
19/3/13	66.83 j-n	61.44 k-o	64.13 K	9.53 f-l	10.18 c-g	9.85 C-E
19/3/14	88.67 gh	92.76 g	90.72 E-G	9.94 e-j	11.48 a	10.71 A
19/3/15	99.00 e-g	110.41 de	104.71 B	9.11 j-n	11.13 ab	10.12 B-D
19/3/16	71.62 i-l	95.99 fg	83.81 G-I	9.41 g-m	11.01 a-c	10.21 A-D
19/3/19	79.29 hi	113.23 d	96.26 C-E	8.81 l-n	10.77 a-e	9.79 DE
19/18/7	91.13 g	65.95 j-n	78.54 IJ	7.69 o	9.47 f-m	8.58 G
19/18/10	55.89 m-o	61.62 k-o	58.75 K	9.47 f-m	9.20 i-n	9.33 EF
19/18/24	75.03 ij	50.79 o	62.91 K	8.46 n	11.01 a-c	9.73 DE
19/26/2	72.42 i-k	74.18 ij	73.30 J	10.77 a-e	10.65 a-e	10.71 A
POJ 2878	54.90 no	39.87 p	47.38 L	9.70 f-k	11.48 a	10.59 AB
Average	73.93 Y	95.47 X		9.38 Y	10.32 X	

Note: Numbers followed by the same letters show no significant difference in the Duncan 5% test.

Stem weight and stem population (number of stems) are two components that influence sugarcane productivity. In this research, the relationship between sugar cane productivity (TCH) and stem weight (SW) and stem population (SP) was obtained by forming the equation TCH = 0.2513 SW + 1.2383 SP -0.3744, with a correlation coefficient (r) of 0.903. The correlation value shows that the total influence of stem weight and stem population on sugarcane productivity is 90.3%. Palachai et al. (2019), Ogunniyan et al. (2020), and Abdurrachman et al. (2022) also showed a positive correlation between sugarcane productivity and the number and weight of stems. The total magnitude of the influence is 2.9% for stem weight and 87.4% for stem population. From the magnitude of the influence of each component, it can be concluded that the increase in sugarcane productivity occurs through an increase in the stem population. Djumali et al. (2018) showed that the effect of stem population on sugarcane productivity was greater than the effect of stem weight.

The highest sucrose content for PC (9.94-10.77%) was produced by clones 19/3/2, 19/3/4, 19/3/5, 19/3/8, 19/3/14 and 19/26/2, and the lowest (7.69%) was produced by 19/18/10. In RC, the highest sucrose content (10.65-11.48%) was produced by 26/19, 3/19/4, 3/19/5, 3/19/14, 3/19/15, 3/19/16, 19 /3/19, 19/18/24, 19/26/2, and POJ 2878, and the lowest (8.75-8.99%) was produced by 19/3/8, 19/3/10, and 19/3/11. In comparison with the female parent, only the 19/26/2 clone produced higher sucrose content (10.77%) than the female parent (9.70%) for PC, whereas for RC, no clones produced higher sucrose content than the female parent (11.48%). From the average of each clone, there was a decrease in sucrose content by 7.41% compared to the female parent (10.59%). However, 8 clones (19/3/2, 19/3/4, 19/3/5, 19/3/14, 19/3/15, 19/3/16, and 19/26/2) produced sucrose content which was no different from the female parent. Of these clones, 3 clones (19/3/5, 19/3/14, and 19/26/2) produced a slight increase (0.28-1.12%). Khurshid et al. (2020) and Afzal et al. (2021) showed that some clones from crosses produced no different sucrose content from the comparison varieties and produced lower sucrose content than the comparison varieties.

Table 6 – Sugar yield of cross-bred sugarcane clones and their female parent in PC and RC and their averages

Clones	Sugar (t/ha)		
	PC	RC	Average
19/3/2	7.89 gh	13.87 a	10.88 A
19/3/4	6.03 jklm	13.70 a	9.86 BCD
19/3/5	7.45 hi	12.95 ab	10.20 ABC
19/3/6	5.69 klmn	9.96 ef	7.82 F
19/3/7	6.06 jklm	10.67 de	8.36 EF
19/3/8	7.28 hij	11.07 cde	9.17 DE
19/3/10	6.27 ijkl	9.76 ef	8.02 F
19/3/11	8.00 gh	11.87 bcd	9.94 BCD
19/3/13	6.35 ijkl	6.23 ijkl	6.29 GH
19/3/14	8.81 fg	10.64 de	9.72 CD
19/3/15	9.03 fg	12.33 bc	10.68 AB
19/3/16	6.76 hijkl	10.48 e	8.62 EF
19/3/19	6.98 hijk	12.10 bc	9.54 CD
19/18/7	6.96 hijk	6.22 ijkl	6.59 G
19/18/10	5.30 mn	5.64 klmn	5.47 HI
19/18/24	6.33 ijkl	5.56 lmn	5.94 GH
19/26/2	7.80 gh	7.90 gh	7.85 F
POJ 2878	5.30 mn	4.57 n	4.93 I
Average	6.90 Y	9.75 X	

Note: Numbers followed by the same letters show no significant difference in the Duncan 5% test.

The highest sugar yield for PC (7.89-9.03 t/ha) was produced by clones 19/3/2, 19/3/11, 19/3/14, and 19/3/15, and the lowest (5.30-6.06 t/ha) was produced by 19 /3/4, 19/3/6, 19/3/7, 19/18/10, and POJ 2878. The highest sugar yield (12.95-13.87 t/ha) for RC was produced by 19/3/2, 19/3/4, and 19/3/5, while the lowest (4.57-5.64 t/ha) was produced by 19/18/10, 19/18/24, and POJ 2878. In comparison to the female parents, for PC, clones 19/3 /4, 19/3/6, 19/3/7, and 19/18/10 produced no different sugar yield, while the other clones produced higher sugar yield than the female parent. For RC, clones 19/18/10 and 19/18/24 produced no different sugar yield, while the other clones produced higher sugar yield than the female parent. From the average of each clone, there was an increase in sugar yield by 72.87% from the female parent (4.93 t/ha). Clone 19/18/10 produced no different sugar yield from the female parent, and the other clones (5.94-10.88 t/ha) produced higher sugar yield than the female parent. Of the clones that produced higher sugar than the female parent, 9 clones produced an increase in sugar of more than 72.87%; these clones are 3/19/2, 3/19/4, 3/19/5, 3/19/8, 3/19/11, 3/19/14, 3/19/15, 3/19/16, and 3/19/19 (74.83-120.57%). Bhavana et al. (2017b) and Ali et al. (2020) showed that there were clones that produced more sugar than the comparison varieties and no different sugar yield from comparison varieties.

Sugarcane productivity and sucrose content are two components that influence the sugar produced. In this research, a relationship was obtained between sugar yield (TSH) and sugarcane productivity (TCH) and sucrose content (SC), forming the equation TSH = 1.003 TCH + 0.7531 SC – 0.6510, with a correlation coefficient (r) of 0.994. The correlation coefficient value describes the total influence of the two components on sugar, which is 99.4%. Hassan et al. (2017) and Khan et al. (2021) show a positive correlation between sugar yield and sugarcane productivity and sucrose content. The influence of sugarcane productivity is 91.5% and sucrose content 7.9% on sugar yield. Thus, it can be concluded that the increase in sugar obtained was caused by an increase in the productivity of the sugarcane. Side et al. (2023) also show that sugarcane productivity has a greater contribution to sugar yield than sucrose content.

CONCLUSION

From the findings and discussion, it can be concluded that apart from clone 19/18/10, all clones tested produced sugar at 5.94-10.88 t/ha, which was an increase of 72.87% from the female parent at 4.93 t/ha. Of the clones that experienced an increase, 9 clones (19/3/2, 19/3/4, 19/3/5, 19/3/8, 19/3/11, 19/3/14, 19/ 3/15, 3/19/16, and 3/19/19) experienced an increase in sugar by 74.83-120.57% or more than 72.87% as compared to the female parents. The increase in sugar produced occurs through increasing sugarcane productivity.

REFERENCES

1. BPS. 2021. Statistik tebu Indonesia 2020. Badan Pusat Statistik, Jakarta.
2. Ditjenbun. 2020. Statistik Perkebunan Indonesia. In: Tebu 20118-2020. Direktorat Jenderal Perkebunan, Kementerian Pertanian, Jakarta.
3. Hamida, R., S. Basuki, F. Rochman, Abdurrakhman. 2018. Plasma nutfah tanaman pemanis. Laporan hasil penelitian Tahun Anggaran 2018. Balai Penelitian Tanaman Pemanis dan Serat, Malang.
4. Kementan. 2010. Surat Keputusan Menteri Pertanian Nomor 3679/Kpts/SR.120/11/2010 tentang pelepasan tebu klon TK 380 dengan nama varietas Cenning. Direktorat Jenderal Perkebunan, Kementerian Pertanian, Jakarta.
5. Heliyanto, B., Abdurrakhman, Djumali, M. Murianingrum. 2019. Perakitan Varietas Tebu dengan Produktivitas dan Rendemen Tinggi untuk Pengembangan di Lahan Kering. Laporan Hasil Penelitian Tahun Anggaran 2019. Balai Penelitian Tanaman Pemanis dan Serat, Malang.
6. Heliyanto, B., R.D. Purwati, Abdurrakhman, Djumali, M. Murianingrum. 2020. Perakitan verietas unggul tebu lahan kering rendemen tinggi dan tahan penyakit luka api. Laporan hasil penelitian Tahun Anggaran 2020. Balai Penelitian Tanaman Pemanis dan Serat, Malang.
7. Sulaeman, Suprapto, Eviati. 2012. Petunjuk teknis analisis kimia tanah, tanaman, air dan pupuk. Balai Penelitian Tanah, Badan Penelitian dan Pengembangan Pertanian, Jakarta.
8. Abu-Ellail, F.F.B., E.M. A. Hussein, A. El-Bakry. 2020. Integrated selection criteria in sugarcane breeding programs using discriminant function analysis. Bulletin of the National Research Centre. 44:161. DOI: 10.1186/s42269-020-00417-6.
9. Ali, M.A., M.S. Hassan, B.D. Mohamed, A.H. Ali. 2021. Evaluation and path-coefficient analysis of some sugarcane clones under Upper Egypt region conditions. SVU-International Journal of Agricultural Sciences. 3(4): 159-171. DOI: 10.21608/svuijas.2021.97093.1143

10. Supriyono, Djumali, B. Heliyanto, F. Rochman, A. Herwati, W.M. Mahayu, D. Hariyanto, D. Utari Dewi. 2023. Improving productivity of POJ 2878 sugarcane variety through plycross with Bululawang, 6535, and Sil 04 varieties. Russian Journal of Agricultural and Socio-Economic Sciences. 4(136): 154-161. DOI 10.18551/rjoas.2023-04.14.
11. Mohammed A. K., M.N. Ishaq, A.K. Gana, S. Agboire. 2019. Evaluation of sugarcane hybrid clones for cane and sugar yield in Nigeria. African Journal of Agricultural Research. 14(1): 34-39. DOI: 10.5897/AJAR2018.13463.
12. Hamida, R., Djumali, B. Heliyanto, Abdurrachman, S. Adikadarsih, M. Murianingrum. 2022. Yield and growth performance of potential sugarcane (Saccharum officinarum L.) hybrid clones. The 2nd International Conference on Sustainable Plantation. IOP Conf. Series: Earth and Environmental Science 974 (2022) 012017. doi:10.1088/1755-1315/974/1/012017.
13. Palachai, CH., P. Songsri, N. Jongrungklang. 2019. Comparison of yield components of sugarcane varieties grown under natural short- and long-term water-logged conditions in Thailand. SABRAO Journal of Breeding and Genetics. 51(1): 80-92.
14. Rakesh, G., G. E. Reddy, N. Swapna, P. J. Naik, Y. Swathi, T. P. Reddy, M. V. Kumar. 2020. Estimation of genetic parameters in early maturing sugarcane clones for yield and quality traits. Journal of Experimental Agriculture International 42(5): 115-121.
15. Getaneh, A., F. Tadesse, N. Ayele. 2015. Agronomic performance evaluation of ten sugarcane varieties under Wonji-Shoa agro-climatic conditions. The Journal of Agriculture and Natural Resources Sciences. 2(1): 260-266.
16. Biradar, V., M. S. Patil, S.B. Mashetty, P. Lachuriye, P. Shrigiri. 2016. Regeneration of somaclones from sugarcane cultivar CO-740 & comparison of their agronomic characters with local varieties. Int. J. Adv. Res. 4(10): 397-406.
17. Jun-Luo, J., Y. Pan, L. Xu, Y. Zhang, H. Zhang, R. Chen, Y. Que. 2014. Photosynthetic and canopy characteristics of different varieties at the early elongation stage and their relationships with the cane yield in sugarcane. The Scientific World Journal. Volume 2014, Article ID 707095, 9 pages. DOI: 10.1155/2014/707095.
18. Mahadevaiah, C., P. Hapase, V. Sreenivasa, R. Hapase, H. K. M. Swamy, C. Anilkumar, K. Mohanraj, G. Hemaprabha, B. Ram. 2021. Delineation of genotype × environment interaction for identifcation of stable genotypes for tillering phase drought stress tolerance in sugarcane. Scientifc Reports. 11:18649 DOI: 10.1038/s41598-021-98002-y.
19. Murianingrum, M., Djumali, P.D. Riajaya, B. Heliyanto. 2020. Responsiveness of new superior clones/varieties of early maturity sugarcane to fertilization. Berita Biologi 19(2): 165-176. DOI: 10.14203/beritabiologi.v19i2.3804.
20. Yulaikah, S., Djumali, A. Herwati, Abdurrakhman, Supriyono, S. Mulyani, M. Sohri. 2023. Clone characteristics of Sil 04, 6535, PS 881, and Bululawang polycross. International Journal of Science, Technology & Management. 4(2): 379-385. DOI: 10.46729/ijstm.v4i2.762
21. Sarwar, M., A. Mehmood, N. Ahmad. 2016. Performance of promising sugarcane varieties/clones at farmer's field in Punjab. Pak. Sugar J. 31(4): 06-08.
22. Sarwar, M., A. Mahmood, M. Younus, N. Ahmad. 2018. Adaptability of promising sugarcane clones/varieties at farmer's field in Thal and Southern Punjab. Pak. Sugar J. 33(2): 23-26.
23. Naidu, P.N., M.G.M. Khan, A. D. Jokhan. 2017. Assessment of sugarcane varieties for their stability and yield potential in Fiji. The South Pacific Journal of Natural and Applied Sciences. 35(2): 20-32. DOI: 10.1071/SP17003.
24. Sarol, R., M.V. Serrano, J. Agsaoay, N. Guiyab, A. Casupanan, B. Manlapaz. 2020. Root density distribution and yield relationships of high yielding sugarcane varieties under sandy soil condition. Review of Plant Studies. 7(1): 1-15.
25. Mahmood-Ul-Hassan, H.M.W.A. Khan, M.A. Mudassir, M.S. Afzal, M. Yasin, W. Muzaffar, M.F. Ahmed, N. Ahmad. 2020. Evaluation of new sugarcane genotypes for biometric traits, resistance to red rot and borers complex under agro-climatic conditions of Faisalabad, Pakistan. Intl. J. Agric. Biol. 23:623–629.

26. Bhavana, S., M.V. Kumar, G.S.M. Bindu, D.V.V. Reddy. 2017a. Study on Morpho-Physiological Characters in Different Clones of Sugarcane (Saccharum officinarum L.). Int. J. Curr. Microbiol. App. Sci. 6(11): 205-217.
27. Sarwar, M., W. Muzaffar, W.R. Arshad. 2019. Evaluation of promising and commercial sugarcane clones at different locations in Thal and Southern Punjab. Pak. Sugar J. 34(3): 16-22.
28. Ogunniyan, D.J., O.O. Olakojo, M.O. Olowolafe, B.O. Ogunruku. 2020. Estimation of genetic parameters in agronomic characters and maturity index of sugarcane (Saccharum spp). Journal of Tropical Agriculture. 58 (2): 147-157.
29. Abdurrachman, M. Murianingrum, Djumali, S. Mulyani, A. Herwati, S. Yulaikah, Supriyono. 2022. The growth and production of potential sugarcane clones in Alfisol soil. Biotika, 4(47): 3-19.
30. Djumali, B. Heliyanto, A.D. Khuluq. 2018. Evaluation of potential sugarcane clones in the upland. J. Agron. Indonesia. 46(3):328-336. DOI: 10.24831/jai.v46i3.21082.
31. Khurshid, MR., N. Ahmad, A. Majeed, M. Zubair, H. Qamar, HB. Ahmad, MS. Afza, MK. Malik, T. Mahmood, M. Aftab, Hafeez-u-Rehman, HS. Bin Mustaf, MA. Zahid, M. Farhan. 2020. Evaluation of new promising sugarcane clones under agro-ecological conditions of Faisalabad, Pakistan. Life Sci J 2020. 17(6):84-88. DOI:10.7537/marslsj170620.08.
32. Afzal, M.S., N. Ahmad, Mahmood-Ul-Haasan, H.B. Ahmad, A. Khaliq, M.R. Khurshid, K.M. Mughal, M. Jawad. 2021. Adaptation of different sugarcane clones of Philippine in semi-arid conditions of Punjab, Pakistan. J Agric. Res. 59(3):251-256.
33. Bhavana, S., M. Vijay-Kumar, G.S. Madhu-Bindu, D.V.V. Reddy. 2017b. Correlation analysis for root, growth, yield and quality parameters of twelve sugarcane clones (Saccharum officinarum L.). Agriculture Update. 12(TECHSEAR-8): 107-2111.
34. Hassan, M.U., N. Fiaz, M.A. Mudassir and M. Yasin. 2017. Exploring the ratooning potential of sugarcane (Saccharum Officinarum L.) genotypes under varying harvesting times of plant crop. Pak. J. Agric. Res. 30: 303-309.
35. Khan, M.A.U., Aslam, M.T., Rehman, A., Nawaz, M., Khan, M.J., Ayub, M.A., Khan, A.A., Rehman, M.A., Shahzad, B.A., Hussain, S., Hassan, M.U. and Ahmad, R., 2021. Ratooning potential of different promising sugarcane clones under varying trench spacing. Journal of Innovative Sciences, 7(1): 71-77. DOI: 10.17582/journal.jis/2021/7.1.71.77.
36. Side, THR., Abdurrakhman, Djumali, A. Herwati, S. Yulaikah, Supriyono. 2023. Developing determination of gamma irradiation dose to increase sugarcane growth and yield. E3S Web of Conferences 373, 03013 (2023). DOI: 10.1051/e3sconf/202337303013.