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IMPROVING PRODUCTIVITY OF POJ 2878 SUGARCANE VARIETY THROUGH POLYCROSS WITH BULULAWANG, 6535, AND SIL 04 VARIETIES

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ABSTRACT
Indonesia's sugar production has not been able to fulfill the national demand; thus, increasing productivity is needed. One of the efforts to increase productivity is creating new superior varieties through polycross. This study aims to produce clones from polycross with higher crystal productivity from their female parents. The study took place in IP2TP Karangploso, Malang, from December 2020 to November 2021. We had 24 polycross clones and one female parent (POJ 2878) arranged in a Randomized Block Design with 2 replications. The results showed that the 14 polycross clones (MLG 19/P5/15, MLG 19/P5/16, MLG 19/P5/19, MLG 19/P5/21, MLG 19/P5/24, MLG 19/P5/27, MLG 19/P5/28, MLG 19/P5/30, MLG 19/P5/31, MLG 19/P5/33, MLG 19/P5/37, MLG 19/P5/44, MLG 19/P5/46, and MLG 19/P5/47) had higher crystal productivity (8.38-13.68 t/ha) than the female parent (7.59 t/ha).

KEY WORDS
Improvement, productivity, sugarcane, crossing, polycross.

Indonesia has produced 2.191 million tons of sugar yearly in the last five years, while the national demand is 3.21 million tons yearly (Dirjenbun, 2022). The rest of the demand is fulfilled with imported sugar due to low sugar crustal productivity at 4.98 tons per hectare (Dirjenbun, 2020). Thus, efforts must be taken to increase crystal productivity to reach self-sufficiency. One of the efforts is creating new superior varieties with advanced technology. Polycross is a method chosen to do so with the hope that the superior traits of the male parents can be gathered at the female parents to produce new superior varieties with higher crystal sugar productivity than the female parents.

POJ 2878 is a superior variety of sugar cane from Indonesia generally used as parents in crosses in almost all countries, including Australia, USA, Colombia, Brazil, Puerto Rico, India, and Taiwan. It has produced offspring which have become superior varieties in various the country. Almost all sugar cane crossing centers use POJ 2878. The Bululawang variety is a medium-slow ripening sugarcane with a high crystal yield and high adaptability to growing environmental conditions. SIL 04 and 6535 clones are potential in production and high yield. The polycross between POJ 2878 and the three male parents (Bululawang, SIL 04, and 6535) is expected to produce new superior varieties with high crystal productivity.

The polycross of POJ 2878 with the three male parents (Bululawang, SIL 04, and 6535) was done in 2019 and produced 148 growing individuals. We got 24 clones with above-average crystal yield in 2020. The following stage would be selecting the chosen clones under the criterion of higher crystal yield than the female parent. This study aims to identify polycross clones with higher crystal yield than the female parent.

MATERIALS AND METHODS OF RESEARCH

The study took place in IP2TP Karangploso, Malang, from December 2020 to November 2021. Table 1 presents the soil condition, and Table 2 presents the rainfall rate during our study. We use bud chips from the 24 polycross clones of POJ 2878 x (Bululawang, SIL 04, and 6535) and one female parent clone as a control. The 11 clones came from the 2020 selection results of the 2019 crossing. We also used the NPK compound fertilizer, manure and other chemicals. The tools used include a tape measure, scales, caliper, refractometer, and other auxiliary tools.

Crossed clones (MLG 19/P5/1, MLG 19/P5/2, MLG 19/P5/6, MLG 19/P5/7, MLG 19/P5/9, MLG 19/P5/11, MLG 19 /P5/15, MLG 19/P5/16, MLG 19/P5/19, MLG 19/P5/20, MLG 19/P5/21, MLG 19/P5/22, MLG 19/P5/24, MLG 19/ P5/25, MLG 19/P5/26, MLG 19/P5/27, MLG 19/P5/28, MLG 19/P5/30, MLG 19/P5/31, MLG 19/P5/33, MLG 19/P5 /37, MLG 19/P5/44, MLG 19/P5/46 and MLG 19/P5/47) and a control variety were arranged in a randomized block design with 2 replications. Each clone or variety in one replication consisted of 1 row with a length of 5 m. The center-to-center (CTC) distance is 110 cm, so the length of the row per hectare (the row factor) is 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 with 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 stalk. The dose of fertilizer given was 600 kg of Phonska and 500 kg of ZA. Phonska fertilizer was given on fertilization I, and ZA fertilizer on fertilization II.

Hilling was done three times by piling soil up around the plant base. Hilling I and II was 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 in the field. 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 stalk base. The shoots of the harvested stalks were trimmed and cleaned of dry leaves. The clean stalks were collected according to the plot number and weighed.

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

$$\text{JBM} = \frac{\text{JB}}{\text{Length of the total row}}$$

The stalk length, diameter, and weight were observed at harvest. We took 10 stalks per plot as the sample. Each sample was observed for its length and diameter. Stalk diameter was observed at the stalk center. Stalk weight was measured by weighing the entire sample. The yield was measured from the squeezed sample plants. The sap produced was measured for juice weight, brix, and pol values. The extraction factor (FP) is calculated by the formula:

$$\text{FP} = \frac{\text{Juice weight}}{\text{Stalk weight}}$$

The juice value (NN) is calculated with the following formula: NN = 0.4 x (brix – pol).

Yield is calculated with the following formula: Yield (%) = FP x NN.

Cane productivity (PROTAS) and crystal productivity (HABLUR) is calculated as:

$$\text{PROTAS} = \frac{8100 \text{ x (stalk weight per plot)}}{\text{The total length of rows}}$$

$$\text{HABLUR} = \text{PROTAS x yield}$$

We analyzed the variance and continued with Duncan's Multiple Range Test (DMRT) at a 5% level using MSTAT software version 4.00/EM. Backward stepwise analysis was used to determine the level of influence of each component on stalk weight, sugar cane productivity, and crystal yields.

Table 1 – Soil Characteristics of the Study Sites (IP2TP Karangploso, Malang)

Soil characteristics	Values	Categories*)
pH 1:1		
• H_2O	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_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
Amount of base (me/100g)	16.60	Low
Base saturation	54	Medium
Texture:		
• Sand (%)	6	Silty clay
• Silt (%)	45	
• Clay (%)	49	

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

Table 2 – Rainfall at the Study Sites (IP2TP Karangploso, Malang) during the Study

Month	Rainfall (mm)	Rainy days (days)
December 2020	254.8	14
January 2021	355.8	22
February 2021	453.5	20
March 2021	389.3	16
April 2021	191.5	9
May 2021	45.5	3
June 2021	238.0	8
July 2021	14.1	1
August 2021	28.0	4
September 2021	90.0	3
October 2021	202.4	15
November 2021	343.2	23
December 2021	291.1	19

RESULTS AND DISCUSSION

The length and diameter of sugarcane stalks are components of plant growth affected by the clones (Table 3). Abu-Ellail et al. (2020) show that the clones selected affect the length and diameter of the sugarcane stalks. The highest stalk length (199.69-211.21 cm) was produced by MLG 19/P5/21, MLG 19/P5/25, MLG 19/P5/27, MLG 19/P5/31 and MLG 19/P5/46 and the lowest (154.9-167.04 cm) was produced by MLG 19/P5/1, MLG 19/P5/7, MLG 19/P5/26, MLG 19/P5/37 and MLG 19/P5/44. The average stalk length produced by the polycross clones was 183.95 cm or decreased by 3.47% from the female parent (190.56 cm). Even though there was a decrease in stalk length, 8 polycross clones MLG 19/P5/6, MLG 19/P5/21, MLG 19/P5/22, MLG 19/P5/25, MLG 19/P5/27, MLG 19/P5/31, MLG 19/P5/33 and MLG 19/P5/46) produced longer stalk lengths than the female parent and 2 clones (MLG 19/P5/15 and MLG 19/P5/47) produced the same length as the female parent. Ali et al. (2020) show that clones from crosses produced varied stalk lengths, from being longer and shorter than or the same stalk lengths with their comparison varieties.

The largest stalk diameter (31.25-33.32 mm) was produced by MLG 19/P5/15, MLG 19/P5/16, MLG 19/P5/19, MLG 19/P5/20, MLG 19/P5/21, MLG 19/P5/ 30, MLG 19/P5/33 and MLG 19/P5/46, and the smallest (21.60-22.09 mm) was produced MLG 19/P5/2 and MLG 19/P5/6. The average stalk diameter produced by the polycross clones was 28.14 mm or decreased by 5.65% from the female parent (29.83 mm). Ten polycross clones (MLG 19/P5/15, MLG 19/P5/16, MLG 19/P5/19, MLG 19/P5/20, MLG 19/P5/21, MLG 19/P5/30, MLG 19/P5 /33 and MLG 19/P5/46, MLG 19/P5/22 and MLG 19/P5/28) produced larger stalk diameters than other polycross clones and the female parent. Sarol et al. (2020) and Ali et al.

(2021) show that clones resulting from crosses produce varied stalk diameters from being longer and shorter than or the same as the comparison varieties.

Table 3 – Growth Variables (length and diameter) of Polycross Clones with the Female Parent of POJ 2878

Clones	Stalk Length (cm)	Stalk Diameter (mm)
MLG 19/P5/1	154.89 l	24.29 h
MLG 19/P5/2	181.13 g-i	22.09 i
MLG 19/P5/6	192.50 c-g	21.60 i
MLG 19/P5/7	167.04 j-l	15.37 j
MLG 19/P5/9	182.03 g-i	24.87 h
MLG 19/P5/11	184.06 f-h	25.75 gh
MLG 19/P5/15	189.75 d-h	31.61 a-c
MLG 19/P5/16	178.67 h-j	31.57 a-c
MLG 19/P5/19	185.75 e-h	31.58 a-c
MLG 19/P5/20	171.02 i-k	32.30 ab
MLG 19/P5/21	208.54 ab	33.32 a
MLG 19/P5/22	195.31 c-f	30.68 b-d
MLG 19/P5/24	182.95 f-i	26.21 gh
MLG 19/P5/25	204.06 a-c	27.38 fg
MLG 19/P5/26	157.75 l	28.44 d-f
MLG 19/P5/27	199.69 a-d	29.00 d-f
MLG 19/P5/28	178.58 h-j	30.51 b-e
MLG 19/P5/30	171.39 i-k	31.66 a-c
MLG 19/P5/31	199.92 a-d	28.65 d-f
MLG 19/P5/33	197.67 b-e	31.31 a-c
MLG 19/P5/37	165.52 kl	28.70 d-f
MLG 19/P5/44	165.55 kl	28.96 d-f
MLG 19/P5/46	211.21 a	31.25 a-c
MLG 19/P5/47	189.75 d-h	28.32 ef
POJ 2878	190.56 d-h	29.83 c-e

Note: Figures with the same letter within one column are not significantly different at Duncan's multi-range test at the 5% level.

Sugarcane productivity is seen from the weight and number of stalks; it is affected by the clones selected (Table 4). Bhavana et al. (2017) show that different clones cause differences in the weight and number of sugarcane stalks produced. The highest stalk weight (1952 kg/stalk) was produced by MLG 19/P5/21, while MLG 19/P5/7 produced the lowest (0.332 kg/stalk). The average stalk weight produced by the polycross clones was 1.260 kg/stalk or decreased by 11.51% from the female parent (1.424 kg/stalk). Even though there was a decrease in stalk weight, 8 polycross clones produced higher stalk weights (1.487-1.952 kg/stalk) than the female parent. The clones with higher stalk weight were MLG 19/P5/15, MLG 19/P5/16, MLG 19/P5/19, MLG 19/P5/20, MLG 19/P5/21, MLG 19/P5/22, MLG 19/P5/33, and MLG 19/P5/46. Afzal et al. (2021) show that clones from crosses produced varied stalk weights from higher and lighter than or the same as the comparison varieties.

Sugarcane stalk weight is influenced by growth components such as stalk length and diameter. In this study, the relationship between stalk weight (Bbat) and stalk diameter (Dbat) and stalk length (Pbat) can be written as Bbat = 0.60058 Dbat + 0.46353 Pbat - 1.563277 with a correlation coefficient (r) of 0.895. These results mean that stalk length and diameter influence 89.5% of stalk weight. The backward stepwise analysis showed that stalk length affected stalk weight by 44.7% and stalk diameter by 44.8%. Thus, increasing stalk weight can be done by increasing stalk length and diameter. Abu-Ellail et al. (2020) and Mahadevaiah et al. (2021) show a positive correlation between stalk weight and stalk length and diameter.

The highest number of stalks (99,758-102,918 stalks/ha) was produced by MLG 19/P5/1 and MLG 19/P5/31, while the fewest (51,840-55,421 stalks/ha) were produced by MLG 19/P5/22, MLG 19/P5/20, and POJ 2878. The average number of stalks produced by the polycross clones was 74,118 stalks/ha, or an increase of 35.01% from the female parent (54,900 stalks/ha). All polycross clones produced a higher number of stalks than the female parent, except MLG 19/P5/22 and MLG 19/P5/20. Sarwar et al. (2018) and Mahmood-Ul-

Hassan et al. (2020) show that clones resulting from crosses produced varied numbers of stalks from higher and fewer than and the same as the comparison varieties.

Table 4 – Productivity Variables (Weight and Number of Stalks) of Polycross Clones with the Female Parent of POJ 2878

Clones	Stalk Weight (kg/stalk)	Number of Stalks (stalk/ha)
MLG 19/P5/1	0.769 j	102918 a
MLG 19/P5/2	0.745 j	76950 b-e
MLG 19/P5/6	0.754 j	79295 b-d
MLG 19/P5/7	0.332 k	76500 b-e
MLG 19/P5/9	0.952 i	63847 f-j
MLG 19/P5/11	1.026 hi	71471 c-g
MLG 19/P5/15	1.593 b-d	66825 e-i
MLG 19/P5/16	1.497 c-e	85860 b
MLG 19/P5/19	1.556 c-e	84240 b
MLG 19/P5/20	1.487 c-e	55421 jk
MLG 19/P5/21	1.952 a	68850 d-h
MLG 19/P5/22	1.548 c-e	51840 k
MLG 19/P5/24	1.060 hi	86116 b
MLG 19/P5/25	1.289 fg	57176 i-k
MLG 19/P5/26	1.074 hi	60750 g-k
MLG 19/P5/27	1.412 ef	83859 b
MLG 19/P5/28	1.393 ef	74769 b-f
MLG 19/P5/30	1.443 d-f	81000 bc
MLG 19/P5/31	1.382 ef	99758 a
MLG 19/P5/33	1.630 bc	58320 h-k
MLG 19/P5/37	1.149 gh	76950 b-e
MLG 19/P5/44	1.172 gh	72090 c-f
MLG 19/P5/46	1.747 b	63847 f-j
MLG 19/P5/47	1.278 fg	80190 b-d
POJ 2878	1.424 d-f	54900 jk

Note: Figures with the same letter within one column are not significantly different at Duncan's multi-range test at the 5% level.

The clones used affect sugarcane productivity, yield, and crystal yields (Table 5). Palachai et al. (2019) show differences in sugarcane productivity, yield, and crystal productivity due to differences in sugarcane clones or varieties used. The highest sugarcane productivity (128.68-137.57 t/ha) was produced by MLG 19/P5/16, MLG 19/P5/19, MLG 19/P5/21 and MLG 19/P5/31, while MLG 19/P5/7 produced the smallest (25.43 t/ha). The polycross clones produced an average sugarcane productivity of 92.01 t/ha, or an increase of 16.89% from that of the female parent (78.71 t/ha). Even though there was an increase in the productivity of the sugarcane produced, 6 polycross clones had a lower sugarcane productivity than the female parent—they were MLG 19/P5/2, MLG 19/P5/6, MLG 19/P5/7, MLG 19/P5/11, MLG 19/P5/25 and MLG 19/P5/26. Ogunniyan et al. (2020) show that clones resulting from crosses produced sugarcane productivity varied from being higher or lower than and the same as the comparison varieties.

The number and weight of stalks influences sugarcane productivity. In this study, the relationship between sugarcane productivity (Protas) and the number of stalks (Jbat) and stalk weight (Bbat) can be written as follows Protas = 0.2844 Jbat + 0.8988 Bbat – 0.1126 with a correlation coefficient (r) of 0.824. The results mean that the combination of the number and weight of stalks affects sugarcane productivity with a total effect of 82.4%. The backward stepwise analysis revealed that the number of stalks only affected sugarcane productivity by 11.4%, while stalk weight affected sugarcane productivity by 71.0%. Thus, the increased productivity in this polycross occurred through an increase in stalk weight. The results of research by Shanmuganathan et al. (2015) and Sheelamary and Karthigeyan (2021) also show a positive correlation between sugarcane productivity and the number and weight of stalks.

The highest yield (10.42-10.53%) was produced by MLG 19/P5/7, MLG 19/P5/24, MLG 19/P5/26 and MLG 19/P5/33, while the lowest (8.22-8.58%) was produced by MLG 19/P5/21, MLG 19/P5/22, and MLG 19/P5/47. The polycross clones produced an average yield of 9.46% or decreased by 2.55% from the female parent (9.70%). Although there was a decrease in yield, 4 polycross clones (MLG 19/P5/7, MLG 19/P5/24, MLG 19/P5/26, and MLG 19/P5/33) had a higher yield, and 8 clones (MLG 19/P5/9, MLG 19/P5/15, MLG 19/P5/16, MLG 19/P5/25, MLG 19/P5/30, MLG 19/P5/31, MLG 19/P5/37, and MLG 19 /P5/44) had no different yield from the female parent. Sarwar et al. (2016) and Rakesh et al. (2020) show that clones resulting from crosses produced varied from higher to lower than and the same as the comparison varieties.

Table 5 – Sugarcane Productivity, Yield, and Crystal Yield of Polycross Clones with the Female Parent of POJ 2878

Clones	Sugarcane Productivity (t/ha)	Yield (%)	Crystal Yield (t/ha)
MLG 19/P5/1	78.91 h-k	9.05 e-g	7.13 i-k
MLG 19/P5/2	57.31 m	8.70 gh	4.99 l
MLG 19/P5/6	59.57 m	8.70 gh	5.17 l
MLG 19/P5/7	25.43 n	10.48 a	2.66 m
MLG 19/P5/9	62.24 lm	9.76 bc	6.09 kl
MLG 19/P5/11	72.69 j-l	9.41 c-e	6.83 jk
MLG 19/P5/15	106.78 c-e	9.70 bc	10.39 cd
MLG 19/P5/16	128.68 ab	9.64 b-d	12.42 b
MLG 19/P5/19	131.08 a	9.41 c-e	12.34 b
MLG 19/P5/20	81.59 h-j	9.35 c-e	7.65 g-j
MLG 19/P5/21	132.22 a	8.22 i	10.85 cd
MLG 19/P5/22	80.88 h-j	8.52 hi	6.89 jk
MLG 19/P5/24	91.44 f-h	10.53 a	9.65 d-f
MLG 19/P5/25	75.93 i-k	9.59 b-d	7.32 h-k
MLG 19/P5/26	66.47 k-m	10.42 a	6.98 jk
MLG 19/P5/27	118.79 bc	8.93 f-h	10.64 cd
MLG 19/P5/28	103.92 de	9.23 d-f	9.59 d-f
MLG 19/P5/30	116.92 bc	9.59 b-d	11.20 bc
MLG 19/P5/31	137.57 a	9.94 b	13.68 a
MLG 19/P5/33	95.64 e-g	10.42 a	9.94 c-e
MLG 19/P5/37	88.18 h-i	9.76 bc	8.63 e-h
MLG 19/P5/44	84.65 g-j	9.94 b	8.38 f-i
MLG 19/P5/46	108.56 cd	9.11 e-g	9.89 c-e
MLG 19/P5/47	102.71 d-f	8.58 hi	8.84 e-g
POJ 2878	78.71 h-k	9.70 bc	7.59 g-j

Note: Figures with the same letter within one column are not significantly different at Duncan's multi-range test at the 5% level.

The highest crystal productivity (13.68 t/ha) was produced by MLG 19/P5/31, and the lowest (2.66 t/ha) was produced by MLG 19/P5/7. The average crystal productivity was 8.67 t/ha, or an increase of 14.21% from that of the female parent (7.59 t/ha). Although there was an increase in crystal productivity, 9 clones (MLG 19/P5/1, MLG 19/P5/2, MLG 19/P5/6, MLG 19/P5/7, MLG 19/P5/9, MLG 19 /P5/11, MLG 19/P5/22, MLG 19/P5/25, and MLG 19/P5/26) had lower crystal productivity than the female parent. Sarwar et al. (2019) show that clones resulting from crosses had varied crystal productivity from higher or lower than the same as the comparison varieties.

Crystal productivity is influenced by sugarcane productivity and yield. In this study, the relationship between crystal productivity (Hablur) and sugarcane productivity (Protas) and yield (Rend) is written in the following formula Hablur = 0.82923 Protas – 0.01377 Rend + 0.07963 with a correlation coefficient (r) of 0.912. This equation means that crystal productivity is influenced by sugarcane productivity and yield, with a total effect of 91.2%. The backward stepwise analysis shows that the effect of yield on crystal productivity is only 11.8%, and sugarcane productivity is 79.4%. Thus, the increase in crystal productivity in this polycross occurs through increased sugarcane productivity. Hassan et al. (2017) and Khan et al. (2021) show a positive correlation between crystal yields and sugarcane productivity and yield.

CONCLUSION

The findings and discussion lead to the following conclusions. From the polycross clones, 14 clones (MLG 19/P5/15, MLG 19/P5/16, MLG 19/P5/19, MLG 19/P5/21, MLG

19/P5/24, MLG 19 /P5/27, MLG 19/P5/28, MLG 19/P5/30, MLG 19/P5/31, MLG 19/P5/33, MLG 19/P5/37, MLG 19/P5/44, MLG 19/P5/46, and MLG 19/P5/47) had higher crystal productivity (8.38-13.68 t/ha) than the female parent (7.59 t/ha).

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