Yield and growth performance of potential sugarcane (*Saccharum officinarum* L.) hybrid clones

R Hamida, Djumali, B Heliyanto, Abdurrachman, S Adikadarsih and M Murianingrum

1 The Indonesian Sweeteners and Fiber Crops Research Institute (ISFCRI), IAARD
Jalan Raya Karangploso Km. 4, PO Box 199, Malang, East Java, 65152, Indonesia

Corresponding author email: h_mee_da@yahoo.com

Abstract. Sugarcane development in Indonesia has been done primarily on dry lands. Therefore developing varieties more suitable to dry-agro-ecological conditions is being attempted as it is easily applicable and economically feasible. This study aimed at assessing the yield of 18 potential sugarcane clones, resulting from crosses with parents which have high productivity. This study used Cenning variety as a control. The research was conducted at Karangploso experimental garden Malang, from October 2019 to September 2020. The research used a randomized block design with four replications. The experimental plot was designed with five rows (5 m length) and rows distance at 110 cm. The evaluation was carried out on the growth and production component. The results showed that genotypes affected the performances of growth and yield characters. All of the clones showed good performances in growth. Clones MLG 18/21/14, MLG 18/42/15 and MLG 18/41/5 had productivity 21.08-34.86 (t/ha) and sucrose content 21.79-38.44 (%) higher than control. The three clones select as promising clones for sugarcane development in dry-agro-ecological land with higher productivity yields.

Keywords: *Saccharum officinarum*, yield test, dry land, potential clones

1. Introduction
Sugarcane is the primary commodity producing sugar in Indonesia. This plant is developed on dry land with very varied levels of land fertility so that the crystal yield obtained is still low, which is around 5.52 t ha\(^{-1}\) [1]. Efforts to increase sugar yield have been carried out by constructing new superior clones of dry land conventionally and unconventionally. Indonesian Sweetener and Fiber Crops Research Institute (ISFCRI) has been constructing conventionally, namely intra and interspecific crosses, since 2013. This cross included proven parents with high productivity and sugar yield and drought resistance donor parents from other species (*Saccharum spontaneum* and *Erianthus sp.*) [2]. The assembly of superior clones has produced new clones with a potential sugar yield of 8.52-10.35 t ha\(^{-1}\).

Although new superior clones with high potential have been obtained, the sugar yield obtained is still low, so it is necessary to carry out the assembly of superior clones on an ongoing basis until the desired sugar yield results are obtained. Moreover, several elders of potential dry-resistant clones have been obtained from exchanges with institutions/individuals such as HCW 438, HCW 40, HCW 440, and GMP 4 [3]. In 2018 the assembly of superior clones was carried out through crosses between superior sugarcane clones by producing 18 new superior clones. These clones need to know the
potential results to be used as material for further testing. Cenning variety is an early ripe variety, so it’s used as a control in this study to find early ripe sugarcane. In Indonesia, especially in East Java, late-ripe sugarcane varieties more developed, so to maintain the stability of the variety, we assemble early-ripe varieties. Therefore, a study was conducted to observe the yield of potential drought-resistant sugarcane clones on dry agro-ecological land. It is hoped that from this research can be obtained clones of sugarcane expect to support the development of sugarcane inland with dry agro-ecological conditions.

2. Materials and methods
The research was carried out at Karangploso experimental garden Malang, from October 2019-September 2020. The research material consisted of single bud planting from 18 potential clones, Cenning variety for control (Table 1), inorganic fertilizer, organic fertilizer, and other chemicals. The experiment tools include meters, scales, calipers, refractometers, and field equipment. Crossed clones and control variety arrange in a Randomized Block Design with four replications. The experimental plot design with five rows (five m length) and rows distance at 110 cm.

Table 1. List of sugarcane clones and control variety tested.

| No | Clones / Varieties | No | Clones / Varieties |
|----|--------------------|----|--------------------|
| 1  | MLG 18/14/5        | 11 | MLG 18/41/2        |
| 2  | MLG 18/15/1        | 12 | MLG 18/41/5        |
| 3  | MLG 18/18/8        | 13 | MLG 18/41/7        |
| 4  | MLG 18/21/3        | 14 | MLG 18/42/15       |
| 5  | MLG 18/21/14       | 15 | MLG 18/44/1        |
| 6  | MLG 18/21/20       | 16 | MLG 18/47/2        |
| 7  | MLG 18/24/2        | 17 | MLG 18/47/6        |
| 8  | MLG 18/37/2        | 18 | MLG 18/52/2        |
| 9  | MLG 18/38/4        | 19 | Cenning            |
| 10 | MLG 18/40/2        |    |                    |

Plant maintenance includes replanting, fertilizing, weeding, repairing channels, irrigation, adherence to leaf sheath, and disease control. Replanting is done two weeks after planting until the plant population becomes normal. Fertilization is done twice at four weeks and three months after planting. Fertilization is carried out in a base area of the plant stem about 10 cm. The dose of fertilizer was 600 kg Phonska and 500 kg ZA. Phonska fertilizer is given at the first fertilization, and ZA fertilizer is provided twice. Pilling was done after fertilization and the plants were 5-6 months old. Irrigation is carried out when the crop appears to have temporarily withered. The control of pests and diseases is carried out according to the level of attack in the field. Adherence to leaf sheath is carried out according to the planting conditions by manually removing the dry leaves. Harvesting is done when the plant is 12 months after planting by cutting the base a stem. Stems were collected according to the plot number and weighed to determine the weight of the stems per plot.

Observations were made before and after harvest. The number of stems counted per row before harvest has a stem length of more than 150 cm and stem diameter more than 2.0 cm in all the branches. The number of stems per meter of the row is calculated by the formula = all stems / the length of the row.

Observations of stem length, diameter, and weight were carried out at harvest. The stems were harvested in 10 stems per plot as sample plants. Each sample plant was observed for its length and diameter. The diameter of the stem was honored at the center of the stem. Stem weight was monitored by weighing all sample plants. The sucrose content is measured from the sample plants that have been squeezed. The sap produced was measured by the weight of juice, brix value, and pol. The squeezed factor (SF) is calculated by the formula: SF = weight of juice / weight of stem.
The value of juice (VJ) is calculated by the formula: 
\[ VJ = 0.4 \times (\text{brix} - \text{pol}) \]
Sucrose content is calculated by the formula: 
\[ \text{Sucrose content (\%)} = SF \times VJ \]
The cane productivity and the sugar yield is calculated by the formula:
\[ \text{cane productivity (t ha}^{-1}) = 8.100 \times \frac{\text{stem weight per plot}}{\text{length of row}} \]
\[ \text{sugar yield (t ha}^{-1}) = \text{productivity} \times \text{Sucrose content} \]

2.1. Statistical analysis:
The data obtained were analyzed for variance and continued with Duncan Multiple Range Test (DMRT) at \( \alpha = 5\% \) level using MSTAT software version 4.00/EM.

3. Results and discussion
Sugarcane growth includes stem length and diameter, stem weight, and the number of stems per meter line on the first plant (PC). Performance parameters of growth and yield of sugarcane and production components of 19 sugarcane clones under dry agro-ecological conditions are presented in Table 2 and 3. Observations showed that sugarcane growth and yield varied among the clones. This indicates that the response of sugarcane plants is strongly influenced by genetic factors, in this case, the clones used. [4] also showed the same thing for stem length characters, [5,6] on stem diameter characters [6] on the character of the number, and length of segments [7,8] on the character of stem weight. Sugarcane stem diameter is influenced by plant genetics and the growing environment [9]. Under homogeneous growing environmental conditions, stem diameter is influenced by plant genetics [10].

| Clones          | Stem Length (cm) | Stem Diameter (cm) |
|-----------------|------------------|--------------------|
| MLG 18/14/5     | 254.35 ± 7.72    | 2.43 ± 0.16        |
| MLG 18/15/1     | 242.97 ± 13.10   | 2.40 ± 0.10        |
| MLG 18/18/8     | 182.11 ± 15.28   | 2.22 ± 0.15        |
| MLG 18/21/3     | 254.84 ± 13.83   | 2.33 ± 0.04        |
| MLG 18/21/14    | 316.89 ± 28.63   | 2.50 ± 0.07        |
| MLG 18/21/20    | 240.31 ± 7.17    | 2.25 ± 0.08        |
| MLG 18/24/2     | 292.71 ± 20.28   | 2.58 ± 0.16        |
| MLG 18/37/2     | 226.95 ± 18.29   | 2.50 ± 0.11        |
| MLG 18/38/4     | 232.24 ± 17.54   | 2.80 ± 0.21        |
| MLG 18/40/2     | 287.21 ± 16.20   | 2.52 ± 0.17        |
| MLG 18/41/2     | 246.88 ± 19.11   | 2.24 ± 0.17        |
| MLG 18/41/5     | 372.27 ± 24.69   | 2.55 ± 0.09        |
| MLG 18/41/7     | 192.84 ± 16.58   | 2.56 ± 0.16        |
| MLG 18/42/15    | 317.58 ± 15.31   | 2.59 ± 0.15        |
| MLG 18/44/1     | 198.13 ± 3.31    | 2.31 ± 0.06        |
| MLG 18/47/2     | 181.90 ± 6.63    | 2.55 ± 0.11        |
| MLG 18/47/6     | 220.70 ± 18.48   | 2.80 ± 0.08        |
| MLG 18/52/2     | 262.40 ± 11.67   | 2.25 ± 0.14        |
| Cening          | 269.74 ± 11.73   | 2.37 ± 0.11        |

Note: Values in the same column followed by the same letters were not significantly different at \( \alpha = 5\% \) level based on the Duncan multiple range test.

The tested clones produced stem lengths ranging from 181.90-372.27 cm, while the comparison clones were 269.74 cm long. The clones MLG 18/41/5, MLG 18/42/15, MLG 18/21/14, and MLG 18/24/2 produced longer stem lengths than the comparison clones. The MLG 18/40/2 and MLG...
18/52/2 clones had no different stem lengths and the other clones produced shorter stem lengths than the comparison clones. The results of [11] research show that in the same treatment of phosphorus fertilizers the difference in stem length obtained is caused by differences in the sugarcane clones used.

The stem diameter obtained by the clones from the 2018 crosses ranged from 2.22–2.80 cm, while the comparison clones had 2.37 cm. Four clones (MLG 18/18/8, MLG 18/21/20, MLG 18/41/2, and MLG 18/52/2) had smaller stem diameters than the comparison clones. Three clones (MLG 18/44/1, MLG 18/21/3, and MLG 18/15/1) had no different diameters, and the other clones produced larger stem diameters than the comparison clones. The results of [12] and [13] showed differences in stem diameter due to differences in sugarcane clones used.

Mathematically, the weight of the rod consists of the volume and density of the rod. The thickness of the rods is assumed to be no different so that the importance of the rods is determined by the volume of the rod. The volume of the rod is composed of the cross-sectional area and the length of the rod, where the cross-sectional area of the rod can be represented by the diameter of the rod so that the weight of the rod can be determined by the diameter and length of the rod. Multiple linear regression analysis of rod weight on diameter and length of rods resulted in an effect value of 79.3%. Clones/varieties with larger stem diameters and longer stem lengths will produce greater stem weights. [14,15] stated that the weight of sugarcane stems is determined by the diameter and length of the stem. If there is no difference in the length of the stem, then the weight of the stem is determined by the diameter of the stem and vice versa [16]. The MLG 18/41/5 clone had the highest stem length and rather large stem diameter, resulting in the largest stem weight (2044.77 g/stem). The clones MLG 18/38/4 and MLG 18/47/6 with short stem length but high stem diameter resulted in moderate stem weight (1463.53-1570.44 g/stem).

The results of [17] showed differences in the number of stems produced due to differences in sugarcane clones/varieties used. One clone (MLG 18/18/8) had more stems harvested, two clones (MLG 18/41/2 and MLG 18/52/2) were not different, and the other 11 clones were more minor than Cenning. The number of sugarcane stalks per unit area of land is influenced by plant genetics and the growing environment [18]. In a homogeneous growing environment, the number of sugarcane stalks is determined by plant genetics [9]. The research results by [19] and [20] showed that genetic differences in sugarcane resulted in differences in the number of sugarcane stalks harvested.

Stem weight and the number of harvested stems are components of sugarcane productivity. Clones/varieties with higher stem weight and more harvested stems resulted in higher sugarcane productivity. [21] and [22] stated that sugarcane productivity is determined by stem weight and the number of stems at harvest. The increase in the number of sugarcane stalks and stem weight led to an increase in sugarcane productivity [23,24]. Considering that stem weight and the number of stems harvested in this study were influenced by plant genetics, sugarcane productivity was also influenced by plant genetics (Table 3). Three clones (MLG 18/42/15, 18/21/14, and 18/41/5) had higher productivity, four clones (MLG 18/24/2, 18/41/2, 18/47/6, and 18/52/2) was not different and the other 11 clones were inferior to Cenning. The study results of [20] and [25] showed differences in sugarcane productivity due to differences in plant genetics used.

**Table 3.** Stem weight and the number of stems per m of sugarcane clones at Karangploso experimental garden, Malang.

| Clones     | Stem weight (g stem⁻¹) | Number of sticks (per m square) |
|------------|-------------------------|---------------------------------|
| MLG 18/14/5 | 1269.38 ± 107.87        | 7.30 ± 1.49                     |
| MLG 18/15/1 | 1171.47 ± 63.88         | 8.11 ± 1.66                     |
| MLG 18/18/8 | 759.62 ± 105.35         | 11.30 ± 1.54                    |
| MLG 18/21/3 | 1161.62 ± 71.34         | 9.18 ± 1.02                     |
| MLG 18/21/14 | 1667.85 ± 94.85       | 9.30 ± 1.22                     |
| MLG 18/21/20 | 1024.63 ± 75.61        | 9.40 ± 1.50                     |
| MLG 18/24/2 | 1652.87 ± 200.21        | 7.50 ± 1.00                     |
The highest productivity was produced by clones MLG 18/42/15 (124.06 t/ha) followed by MLG 18/21/14 (121.42 t/ha) and MLG 18/41/5 (111.39 t/ha) (Table 4). The productivity of these three clones was higher than the Cenning variety. The average national productivity of sugarcane is below 70 t/ha [2]. Cane productivity above 70 t ha⁻¹ on dry land is already high [26].

Sucrose content is the second major component in sugarcane cultivation. In this study, the sucrose content was influenced by the clones used (Table 4). Similar results were reported by (26) and (3). Table 4 shows that the sucrose content of the tested clones varied from 7.81% to 10.65%. The highest sucrose content was produced by MLG 18/14/5 (10.65%), followed by MLG 18/21/20 (10.59%), MLG 18/52/2 (10.48%). The sucrose content of the three clones was higher than the comparison variety Cenning (9.70%). Sugarcane clones grown on dry land with sucrose content above 10% have a high potential for sugarcane development in a dry land.

Sugarcane productivity and sucrose content are the main components of sugar yield [27]. In this study, it was found that cane productivity and sucrose content were influenced by the clones used so that the sugar yield was influenced by the sugarcane clones used (Table 4). The clones produced sugar yield ranging from 3.83-12.39 t/ha, while the comparison clones (Cenning) produced 8.95 t/ha. The clones that produced higher sugar yield than Cenning were MLG 18/21/14 (12.39 t ha⁻¹), MLG 18/42/15 (11.00 t ha⁻¹) and MLG 18/41/5 (10.90 t ha⁻¹). The clones that produced no different sugar yield from Cenning were MLG 18/24/2 (9.91 t ha⁻¹) and MLG 18/52/2 (9.96 t ha⁻¹), while the other clones produced lower sugar yield. Research [28] and [29] also resulted in the effect of sugarcane clones on the sugar yield obtained.

**Table 4.** Cane productivity, sucrose content, and sugar yield of sugarcane clones at Karangploso experimental garden, Malang

| Clones     | Productivity (t ha⁻¹) | Sucrose content (%) | Sugar yield (t ha⁻¹) |
|------------|-----------------------|---------------------|----------------------|
| MLG 18/14/5 | 73.84 ± 8.74 de       | 10.65 ± 0.58 a      | 7.90 ± 1.25 cde      |
| MLG 18/15/1 | 76.39 ±7.95 de        | 9.35 ± 0.49 bc      | 7.18 ± 1.46 de       |
| MLG 18/18/8 | 68.47 ±9.52 ef        | 10.24 ± 0.30 bc     | 7.01 ± 0.97 de       |
| MLG 18/21/3 | 85.66 ±4.82 cde       | 10.18 ± 0.51 bed    | 8.71 ± 0.48 cd       |
| MLG 18/21/14 | 121.42 ±15.23 a       | 10.12 ± 0.53 bcd    | 12.39 ± 3.49 a       |
| MLG 18/21/20 | 77.40 ±7.84 cde       | 10.59 ± 0.36 a      | 8.22 ± 1.73 cde      |
| MLG 18/24/2 | 99.25 ±8.04 bc        | 10.00 ± 0.30 cdef   | 9.91 ± 1.47 bc       |
| MLG 18/37/2 | 69.33 ±9.49 ef        | 9.94 ± 0.00 cdef    | 6.89 ± 0.94 de       |
| MLG 18/38/4 | 48.40 ± 5.12 fg       | 9.70 ± 0.34 fgghi   | 4.70 ± 0.57 fg       |
| MLG 18/40/2 | 74.95 ±5.49 de        | 9.41 ± 0.23 phi     | 7.06 ± 0.63 de       |
In this study, comprehensively, clones MLG 18/21/14, MLG 18/42/15, and MLG 18/41/5 were selected as promising clones for sugarcane development in dry-agro-ecology land with higher yields. The three clones result from biparental crossing of *S. officinarum*. There are consist of clone 2012 with Kentung, clone 31235 with clone 2012, and clone 2161 with clone SIL 04.

4. Conclusions

The growth and yield of sugarcane on land with dry agroecology varied between clones. MLG 18/21/14, MLG 18/42/15, and MLG 18/41/5 were selected as promising clones to support sugarcane development in a dry land with the highest productivity, sucrose content, and sugar yield. Therefore, this clone needs to be tested in multiple locations to be released as a new high-yielding variety for sugarcane development in the dry land.

Acknowledgments

The authors would like to thank the Director of The Sweetener and Fiber Crops Research Institute for funding this research through DIPA in 2019 – 2020. Their thank the Head of The Karangploso Experimental Garden, and their staff, and all those who had helped carry out this research activity.

References

[1] Direktorat Jenderal Perkebunan 2020 Statistik Perkebunan Indonesia. In: Tebu 2018-2020 p. 40 pp.

[2] Heliyanto B, Djumali, Abdurakhman, Basuki S 2016 Perakitan varietas tebu dengan produktivitas dan rendemen tinggi untuk pengembangan di lahan kering Research report Indonesian Sweetener and Fiber Crops Research Institute 45 p.

[3] Heliyanto B, Djumali, Abdurakhman, Basuki S 2015 Perakitan varietas tebu dengan produktivitas dan rendemen tinggi untuk pengembangan di lahan kering Research report Indonesian Sweetener and Fiber Crops Research Institute 45 p.

[4] Twii M, Mekbib F, Abraha E 2016 Multivariate analysis of sucrose content contributing traits in sugarcane (*Saccharum officinarum* L.) in Ethiopia *African J. Plant Sci* 10(8) 145-156.

[5] Gomathi R, Rao PNG, Rakkyappan D, Sundara BP, Shiymala S 2013 Physiological studies on ratoo ability of sugarcane varieties under tropical Indian condition *American J. Plant Sci* 4 274-281.

[6] Ahmed M, Baiyeri KP, Echezona B 2014 Evaluation of organic mulch on the growth and yield of sugarcane (*Saccharum officinarum* L.) in a southern guinea savannah of Nigeria *The Journal of Animal & Plant Sciences* 24 329–335.

[7] Khan IA, Bibi S, Yasmin S, Khatri A, Seema N, Abro AS 2012 Correlation studies of the agronomic traits for higher sur yield in sugarcane *Pak J. Botany* 44(3) 969-971.

[8] Tolera B, Diro M, Belew D 2014 Effects of 6-benzyl aminopurine and kinetin on in vitro shoot multiplication of sugarcane (*Saccharum officinarum* L.) varieties *Advances in Crop Sciences and Technology* 2 1–5.
[9] Naga-Madhuri KV, Kumar MH, Sarala NV 2011 Influence of higher doses of nitrogen on yield and quality of early maturing sugarcane varieties Sugar Tech 13(1) 96-98.
[10] Rahman MA, Eusufzai SUK, Tabriz SS, Hossain SMI 2008 Optimization of irrigation level for selected sugarcane varieties in AEZ-11 of Bangladesh The Agriculturists 6 99-107.
[11] Ahmed AZ 2017 Response of three sugarcane varieties to phosphorous biofertilization Egypt. J. Agron 39 149-158.
[12] Pedrozzi CA, Jifar J, Barbosa MHP, Silva JAD, Park J, Gracia NS 2015 Differential morphological, physiological and molecular responses to water deficit stress in sugarcane J. Plant Breeding and Crop Sci 7(7) 226-232.
[13] Tena E, Mekbib F, Ayana A 2016 Genetic diversity of quantitative traits of sugarcane genotypes in Ethiopia Am. J. Plant Sci. 7 1498-1520.
[14] Junejo S, Kaloi GM, Panwar RN, Chohan M, Junejo AA and Soomro AF 2010 Performance of newly developed sugarcane genotypes for some qualitative and quantitative traits under Thatta conditions Journal of Animal and Plant Sciences 20 40–43.
[15] Shakoor-Ruk A, Kandhro MN, Khan-Balo S, Ullah-Balo S, and Bakhsh-Balo A 2014 Impact of sett placement method and row directions on sugarcane variety LRK-2001 Persian Gulf Crop Protection 3 53–59.
[16] Ghaffar A, Ehsanullah, Akbar N, Khan SH, Jabran K, Hashmi RQ, Iqbal A, and Ali MA 2012 Effect of trench spacing and micronutrients on growth and yield of sugarcane (Saccharum officinarum L.) Australian Journal of Crop Science 6 1–9.
[17] Chohan M, Talpur UA, Junejo O, Unar GS, Panwar RN, Pa B 2014 Selection and evaluation of the diverse sugarcane genotypes in 4th stage J. Anim. Plant Sci 24 (1) 197-203.
[18] Bashir S, Ali A, Yasin M 2005 Sugarcane varieties and row spacing on sugarcane traits Pakistan Sugar J 20 18-20
[19] Dashora P 2012 Productivity and sustainability of sugarcane (Saccharum officinarum) genotypes under planting seasons and fertility levels in South-East Rajasthan Academia Arena 4(1) 37–41.
[20] Tahir M., Khalil IH, Rahman H 2014 Evaluation of important characters for improving cane yield in sugarcane (Saccharum sp.) Sarhad J. Agric 30(3) 320-323.
[21] Soomro AF, Tunio S, Oad FC, Rajper I, Khuhro MI and Arain MY 2012 Effect of supplemental inorganic NPK and residual organic nutrients on sugarcane ratoon crop International Journal of Scientific & Engineering Research 3(10) 1–11.
[22] Tyagi VK, Sharma S, and Bhardwaj SB 2013 Pattern of association among cane yield, sugar yield and their components in sugarcane (Saccharum officinarum L.) Journal of Agricultural Research 59 29–38.
[23] Khalid S, Munsif F, Ali A, Ismail M, Haq N, Iqbal S, Saeed M 2015 Evaluation of chipbud settling of sugarcane for enhancing yield to various row spacing Inter. J. Agric. Environ. Res. 12 41-48.
[24] Djumali, Lestari, and Supriyono 2017 Penampilan tebu dari benih bagal dan budchop pada dua tata tanam di lahan kering J. Agron. Indonesia 45(3) 299-307.
[25] Kumar N, Singh H, Kumar R, Singh VP 2012 Productivity and profitability of different genotypes of sugarcane (Saccharum spp) as influenced by fertility levels and planting seasons Indian J. Agron 57(2) 180-185.
[26] Santosro B, Mastur, Djumali, Nugrahenci SD 2015 Uji adaptasi varietas ungul tebu pada kondisi agrokologi lahan kering J. Littri 21 109-116.
[27] Islam MS and Begum MK 2012 Comparative studies of chlorophyll content, yield, and juice quality of eight sugarcane varieties J. Agrofor. Environ 6(1) 121-124.
[28] Yang Y, Gao S, Jiang Y, Lin Z, Luo J, Li M, Guo J, Su Y, Xu L, Que Y 2019 The physiological and agronomic responses to nitrogen dosage in different sugarcane varieties Frontiers in Plant Sci 10 406.
[29] Tawadere R, Thangadurai D, Khandagave R, Sangeetha J, Pandhari R 2019 RAPD analysis of sugarcane cultivars for early maturation and yield improvement Plant Archives 19(2) 2481-2486.