Yield test of newly collected genotypes of sugarcane under the dry agro-ecological condition

B Helianto* and Abdurrakhman
Indonesian Sweetener and Fibre Crop Research Institute (ISFCRI)
Jalan Raya Karangploso PO Box 199, Malang, East Java, Indonesia 65152

Corresponding author email: b.heliant@gmail.com

Abstract. At present, the majority (>80%) of sugarcane cultivation in Indonesia is done in dry areas. The development of tolerant variety to dry agro-ecological conditions is one of the strategies to increase sugar production. To start with several genotypes from germplasm collections were assessed for their yield potential under dry ecological conditions. The research was carried out in dry land to test the yield performance of twelve potential genotypes of different maturity and two standard varieties. The research was done at Asembagus, Situbondo, East Java using a randomized block design with three replications. Plot size was 5 m x 10 m, whereas the distance from center to center was 1 m. The parameters observed were plant height, stem diameter, no of stalks per meter row, stalk weight per kg, stalk weight (cane yield) per hectare (TCH), sucrose content (CCS), and sugar yield per ha (SCH). Results revealed that genotypes affected the growth and yield performances of the crop. None of the late-maturing genotypes surpassed the yield of the control varieties. Genotypes PI-Pringu and PI-CYZ of early maturing type were found promising; their SCH values were up to 14 % higher than the control early maturing Variety (PS 881).

Keywords: Saccharum officinarum, dry land, early and late maturity.

1. Introduction
Sugarcane (Saccharum officinarum L.) is one of the most important cash crops in the world. This crop has been reported to have high economic value, especially as a producer of sugar for household consumption. In addition, sugar is also the main ingredient for foods and beverages, besides various usage in pharmaceutical industries as well [1]. In the era of the 1930s, Indonesia was the largest sugar exporter in the world, but now Indonesia is one of the world's largest importers [2, 3], with a value of around US$ 900 million or equivalent to 2 million tonnes of sugar every year. These changed conditions have been attributed to several reasons. First, due to increasing domestic sugar consumption, second, unsupportive agricultural policies, third, increased conversion of agricultural land in Java to home and housing, fourth, the shift in sugarcane cultivation from irrigated paddy fields to rainfed and marginal land due to intense competition with food crops, and fifth, lower both production and productivity of the crop [4, 5].

The shift of land for sugarcane development in Indonesia, especially in Java Island, from what was originally in paddy fields to more than 80% of dry, rainfed areas need to be anticipated wisely. The dry, rainfed area is generally characterized as having low to moderate fertility and water availability as limiting factors. The use of high-yielding sugarcane varieties that are tolerant to drought stress is therefore considered imperative [6]. This technology is expected to support the development of
sugarcane in areas that have dry agro ecology. It is reported that the use of high-yielding varieties could make a major contribution, through increasing productivity by 23-46% [7]. Currently, one of the recommended tolerant varieties for the upland region is PS 881. But, its productivity varies across locations

Based on the above considerations, efforts to develop sugarcane varieties suitable for dry land have been carried out both conventionally and unconventionally. Conventionally, intra-specific and inter-specific crosses have been carried out since 2010. These crosses involved proven parents with high productivity and yields as well as drought resistance donors from other species (Saccharum spontaneum and Erianthus) [4]. From the results of these crosses, three potential drought-resistant genotypes were identified, namely, MLG 1308 and MLG 10189 [8]. Unconventionally, genetically engineered products (GM) have been developed by transferring drought resistance genes from Rhizobium meliloti to the sugarcane genome of the Bulu Lawang (BL) variety. From this activity, several dry tolerant PRGs were obtained, one of which has been released for commercial cultivation, i.e. NXI-1T [1]. In addition to the above crossing and selection efforts, several potential genotypes were also obtained from exchanges with institutions/individuals, namely, PI-Pringu, PI-CYZ, PI-CP 80716, PI-R14, PI-6535, PI-3704, PI-3702, PI-6542, PI-6242, PI-UTh, PI-DM, PI-R14, PI-BLE 2.

The purpose of this study was then, to determine the yield potential of those newly acquired genotypes under dry agro-ecological conditions. It is hoped that from this research some genotypes could be used directly or indirectly, in the development of HYV sugarcane varieties suitable for the upland region.

2. Material and methods
2.1. Location study
This research was conducted from January to December 2019, at the Asembagus Experimental Garden, Situbondo regency, East Java Province. The Experimental Garden is located at 5 m above sea level, with climate type E (wet months: 4-months and dry months: less than eight months), average rainfall of less than 1000 mm/year. Rainfall is classified as low with an average monthly rainfall of less than 100 mm in a year, with rainy days each month ranging from 8-17 days. The soil classification type is Entisol with the physical and chemical properties listed in table 1. All of the above data substantiate the dry and marginal conditions of the site used.

2.2. Genetic material
A total of 15 genotypes were tested in this research, comprising of four early maturing genotypes (PI-Pringu, PI-CYZ, PI-CP807162, PI-R14) and nine late maturing genotypes (PI-6535, PI-3704, PI-3702, PI-6542, PI-6242, PI-UTh, PI-DM, PI-R15, PI-BLE 2) along with their respective standard control varieties, namely PS 881 (for early-type) and BL (for late-type). The genotypes tested in this study were the result of the in country-exchange program between ISFCRI (Balittas) and local sugar estates or private companies. The PS-881 and BL varieties were selected as standard control varieties because it is either tolerant and recommended variety for upland areas or the most preferred variety of the cane farmer's.

2.3. Method of study
The research was carried out using a randomized block design with three replications. The plot size was 5 rows of 10 m length or equal to 50 m², whereas the distance from row to row (RRS) was 1 m apart and spacing within the row was 50 cm. Two-eyed setts were planted on rows with a population density of 30 setts per row. Planting was carried out in January 2019. Plant maintenance included replanting, fertilizing, weeding, irrigation, ridging, and pest and disease control. Replanting of the non-germinated setts was carried out two weeks after planting by sowing the available seedlings until the plant population became optimal statistically. The recommended fertilizer dose was 185 kg N + 60 kg P₂O₅ + 60 kg K₂O + 180 kg S/ha or equivalent to 400 kg Phonska + 600 kg ZA / ha. All doses of Phonska fertilizer and 1/3 dose of ZA fertilizer were given as first fertilization at 3-4 weeks-old plants. The remaining ZA fertilizer was given as second fertilization at 3 months-old plants. Fertilization is carried out in a furrow at a 10
3 cm distance from the base of the plant. Ridging is done twice by pulling the soil surrounding the plant to cover the base of the plant, and it is done after the first and second fertilization, respectively. Irrigation was applied before fertilization and if no rain occurs. Pest control was carried out when needed.

| Soil characteristics                  | Value  | Categories  |
|--------------------------------------|--------|-------------|
| pH 1:1 H₂O                           | 7.0    | Neutral     |
| EaspH KCl 1 N                        | 6.8    | Neutral     |
| C-Organic (%)                        | 0.56   | Very low    |
| N-total (%)                          | 0.06   | Very low    |
| C/N                                  | 9.3    | Low         |
| P Olsen (mg kg⁻¹)                    | 51.38  | Very high   |
| K(NH₄OAC 1N pH:7)(me/100 g)          | 1.42   | Very high   |
| Na (NH₄OAC 1N pH:7)(me/100 g)        | 1.09   | Very high   |
| Ca (NH₄OAC 1N pH:7)(me/100 g)        | 11.58  | High        |
| Mg (NH₄OAC 1N pH:7)(me/100 g)        | 1.81   | Medium      |
| CEC (me/100 g)                       | 15.87  | Low         |
| Total bases                          | 15.90  |             |
| Base Saturation (%)                  | 100    | Very high   |
| Sand (%)                             | 81     |             |
| Silt (%)                             | 19     | Sandy Loam  |
| Clay (%)                             | 0      |             |

2.4. Data collection
Harvesting was done 12 months after planting by cutting down all the stalks more than 1.5 m long and at least 2.0 cm in diameter on the second to the fifth row, leaving out the first row. Harvested stalks were cleaned of leaves and tips. Observations of growth and yield components were carried out on plant height, base diameter of the stalk, the weight of stalk per kg, number of stalks per meter row, cane yield per hectare (TCH), mill extraction factor, juice value, commercial cane sugar (CCS), and sugar yield per hectare (SCH).

Commercial cane sugar (CCS) is a function of mill extraction factor (ME), Brix, Pol, and cane juice value (JV). To calculate the value, the harvested cane stalks were taken 10 samples to be weighed and squeezed to take the juice. Mill extraction factor (ME) was then calculated by this formula:

\[
ME = \text{weight of cane juice/ stalk weight.}
\]

Next, Brix and Pol were measured using a Saccharomat machine. The collected Brix and Pol values were used to estimate Cane juice value (JV) by the formula:

\[
JV = \text{Pol-\{0.4-x (Brix-Pol)\}}.
\]

Then, using the above data, CCS can be calculated by this formula:

\[
CCS = ME \times JV
\]

Similarly, sugar yield per hectare (SCH) which is a function of CCS and TCH can be calculated using the following formula:

\[
SCH = CCS \times TCH.
\]
2.5. Statistical analysis
The collected data were analyzed for variance using MSTAT version 5.1 software. The Least Significant Difference Test (LSD) at the 5% level was carried out to determine the differences between treatments.

3. Results and discussion
3.1. Growth components
The growth components parameters of 15 sugarcane genotypes under dry agro-ecological conditions are presented in Table 2. It can be seen that the growth of sugarcane varies between genotypes. This shows that the response of sugarcane plants is strongly influenced by genetic factors, in this case, the genotype used. Similar results were reported by other researchers across the globe for the character of plant height [9, 10], stalk diameter [9, 10, 11], the number of stalks, and weight of stalk [11, 12, 13, 14].

The study of Table 2 also shows that growth components parameters of sugarcane genotypes are irrespective of maturity types. Among the tested genotypes under the late types, the highest height was produced by BL (the control variety), whereas the lowest height was recorded by PI-3702. In the early types, although the lowest height of 252 cm was recorded by PI-Pringu, however, this height value is still considered good for upland development areas as it is above 250 cm [11] and statistically is not different from the control variety PS-881(271 cm). The other three genotypes of late types, namely PI-CYZ, PI-CP 807162, and PI-R14 although they had higher values than the standard variety (BL), however, were insignificantly different. For lateral growth shown by an increase in thickness of the girth, the highest stalk diameter was achieved by PS-881, followed by PI-Pringu. While, least growth was shown by PI-CYZ, PI-CP 807162 dan PI-R14. In the late-maturity group, PI-DM had the best diameter growth followed by PI-3704, PI-3702. Whereas, the lowest diameter performer was achieved by PI-R15.

### Table 2. Growth performances of newly collected sugarcane clones at Asembagus experimental station in 2020 growing season.

| Clone         | Maturity type | Plant height (cm) | Diameter (mm) | Stalk weight (kg/stalk) | # stalks per meter row |
|---------------|---------------|-------------------|---------------|-------------------------|------------------------|
| PI-PRINGU     | Early         | 252.03            | 28.71         | 1.559                   | 10.94                  |
| PS 881(control) | Early     | 271.60            | 29.76         | 1.370                   | 11.08                  |
| PI-CYZ        | Early         | 296.60            | 24.71         | 1.366                   | 11.40                  |
| PI-CP 807162  | Early         | 292.07            | 23.62         | 1.088                   | 13.59                  |
| PI-R14        | Early         | 305.50            | 24.44         | 1.282                   | 12.74                  |
| PI-6535       | Late          | 262.17            | 26.72         | 1.524                   | 11.46                  |
| PI-3704       | Late          | 280.80            | 30.70         | 1.654                   | 8.46                   |
| PI-3702       | Late          | 213.53            | 30.08         | 1.211                   | 10.27                  |
| PI-6542       | Late          | 301.07            | 26.91         | 1.638                   | 11.86                  |
| PI-6242       | Late          | 273.43            | 26.58         | 1.281                   | 12.30                  |
| PI-UTH        | Late          | 303.00            | 29.88         | 1.936                   | 10.22                  |
| PI-DM         | Late          | 285.30            | 32.43         | 1.693                   | 11.16                  |
| PI-R15        | Late          | 319.73            | 24.81         | 1.100                   | 12.74                  |
| PI-BLE 2      | Late          | 282.03            | 26.98         | 1.002                   | 12.74                  |
| BL(control)   | Late          | 319.50            | 28.49         | 1.378                   | 13.28                  |
| **LSD 5%**    |               | 24.07             | 1.38          | 0.19                    | 0.71                   |
| **CV (%)**    |               | 5.07              | 2.98          | 8.23                    | 3.66                   |

**Note:** LSD= Least significant difference; CV= Coefficient of variation

3.2. Yield and its contributing characters
Cane yield per hectare (TCH) is the main consideration for sugarcane growers. Farmers prefer to grow varieties that have good cane yield per hectare because up till now the Sugar Mills administrators don't pay much attention to the real CCS value of the harvested cane stalks. At any given stage of harvest,
they give a fixed-CCS value and hence, the same price. Therefore, the more weight they produce the higher the money will the farmers get. For TCH character, much research has shown that cane yield is affected by its component characters, viz. stalk weight and number of stalks per row [4, 11]. This research results here also found that stalk weight and the number of stalks per meter row seem to correlate with cane yield per hectare (TCH) both in early and late types. The higher the stalk weight coupled with a relatively high number of stalks per meter row the higher the cane yield per hectare will be (Table 2 and Table 3). In the early types, the highest TCH value per hectare (117.96 tons) and significantly different from the control PS 881 variety was recorded by genotype PI-Pringu. Whereas in the late-types, the genotype PI-UTH achieved the best TCH, e.g. 136 tons, but statistically did not differ from the control BL variety (table 3).

**Table 3.** Yield and its components of newly collected sugarcane clones at Asembagus Experimental Station in 2020 growing season.

| Clone         | Maturity | TCH (tones/ha) | ME (%) | JV (%) | CCS (%) | SCH (tones/ha) |
|---------------|----------|----------------|--------|--------|----------|----------------|
| PI-PRINGU     | Early    | 117.96         | 0.796  | 10.26  | 8.13     | 9.62           |
| PS 881(control)| Early    | 104.42         | 0.790  | 10.46  | 8.22     | 8.56           |
| PI-CYZ        | Early    | 106.72         | 0.710  | 12.84  | 9.11     | 9.78           |
| PI-CP 807162 | Early    | 102.13         | 0.755  | 11.40  | 8.34     | 8.65           |
| PI-R14        | Early    | 113.03         | 0.642  | 8.41   | 5.38     | 6.21           |
| PI-6535       | Late     | 119.91         | 0.509  | 13.95  | 7.04     | 8.46           |
| PI-3704       | Late     | 95.93          | 0.548  | 15.28  | 8.38     | 8.02           |
| PI-3702       | Late     | 84.80          | 0.627  | 13.87  | 8.77     | 7.49           |
| PI-6542       | Late     | 132.65         | 0.581  | 14.08  | 8.16     | 10.77          |
| PI-6242       | Late     | 136.55         | 0.606  | 11.08  | 6.78     | 9.45           |
| PI-UTH        | Late     | 108.44         | 0.574  | 15.16  | 8.54     | 9.30           |
| PI-DM         | Late     | 129.09         | 0.694  | 8.85   | 6.11     | 7.75           |
| PI-R15        | Late     | 96.39          | 0.760  | 9.73   | 7.38     | 7.06           |
| PI-BLE 2      | Late     | 87.67          | 0.673  | 10.56  | 7.10     | 6.31           |
| BL(control)   | Late     | 125.19         | 0.733  | 14.54  | 10.62    | 13.12          |

LSD 5%: 1.70, CV (%): 6.53

Note: TCH= cane yield per ha; ME= Mill extraction value; JV= Cane juice value; CCS= Commercial cane sugar. SCH= Sugar yield per ha; LSD=Least Significant Difference; CV= Coefficient of variation

The commercial cane sugar (CCS) or locally known as rendemen represents the total recoverable sugar content from sugarcane cane crushed by the Sugar Mills. Hence, it is considered as one of the important factors for higher and successful sugar production. CCS is determined from the analysis of Brix and Pol of the first expressed juiced at the first pair of rolls. The Brix number indicates the percentage of total dissolved sugar contained in sugarcane stalks, while the Pol represents the percentage of dissolved sucrose contained in the stalks of sugarcane. Putting those two intercorrelated characters (Brix number and Pol) [15, 16] in the formula, the estimated CCS (%) of the 15 genotypes tested of different maturity types is presented in table 3. It shows that CCS was strongly influenced by the genotype used. Similar results were reported by other workers [4, 8, 11, 13, 14]. The study of table 3 also shows that the highest CCS was achieved by BL (10.62%) followed by wi PI-CYZ (9.1%). It is interesting to be noted here that in the early types, the genotypes PI-Pringu and PI-CP 807162 recorded the CCS value at par with the control PS 881 variety. Whereas, in the late types, no newly acquired genotypes surpassed the CCS of the control variety.

In addition to cane yield (TCH) and CCS, sugar yield (SCH) is another important factor for sugar Mills and industries. In this study, the SCH was strongly affected by the genotype used (Table 3). This is in line with other research fellows working on sugarcane [4, 11]. When examined, in the early group,
the genotype PI-Pringgu and PI-CYZ recorded the highest SCH although statistically not different from the control variety PS 881. Whereas, in the late group the highest SCH number was achieved by the control BL-variety.

The yield test is an important stage in a breeding program to select the promising genotypes to be used for advanced study [17]. The selected genotypes will be used for further assessment for their adaptability in several locations. High-yielding genotypes with high stability will be released as broad spectrums high-yielding varieties, while high-yielding genotypes with narrow adaptations will be released as site-specific varieties [6]. In this study, taking into account the results obtained on the three main characters in sugar industries, namely, TCH, CCS, and SCH (Table 2 and Table 3), the genotypes PI-Pringgu and PI-CYZ of the early maturing types were considered promising (figure 1) and selected for further study in the breeding program for increased production in upland areas especially to develop early maturing HYV sugarcane variety. Their sugar yields were approximately up to 14% higher than the control varieties. Whereas, in the late-maturing types, in terms of sugar yield per hectare no one excelled the control variety BL. The reasons for higher growth and yield of the promising genotypes than others are probably related to physiological factors. Those are better in supporting photosynthetic machinery, maintaining cell wall integrity, and improving antioxidant activities that resulted in better recovery and relatively high yield, and better juice quality [18].

![Figure 1. Promising genotypes PI-CYZ and PI Pringgu with the control PS-881 variety.](image)

4. Conclusion

The growth and yield, and their contributing characters of newly collected accessions under dry agroecology conditions varied between genotypes. The two early-maturing genotypes PI-Pringgu and PI-CYZ had better TCH and SCH values compared to the standard control variety PS 881. Whereas, none of the late-maturing type genotypes outclassed the standard control variety BL.

There are two possible uses of the promising genotypes found in this study. First, they can be incorporated into the yield multi location trial [6] along with other promising genotypes resulted from the sugarcane crossing program done by ISFCRI. Second, they can be utilized as parental genotypes in crossing programs to develop high-yielding and early maturing varieties.
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