Field evaluation of the potential of drought-tolerant sugarcane (Saccharum officinarum L.) mutants based on morpho-agronomic characters

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Abstract. A mutation scheme followed by an in-vitro selection is one of the breeding tools for developing drought-tolerant sugarcane varieties. This study aimed to select the drought-tolerant sugarcane mutants. Twenty-seven mutant genotypes that passed the in-vitro selection for drought-tolerant and a Bululawang variety as control were examined in this study. The field evaluation was done in Asembagus, Situbondo, East Java, from January 2019 to December 2020. The four-month-old plants were exposed to drought conditions for two months period. The experiment used a Randomized Complete Block Design with three replications. The observations were made on morpho-agronomic parameters such as a leaf, leaf sheath, internode, stem, bud characters, stem length, diameter, stem weight, internode's number and length, yield, and Brix. Results showed that three mutant genotypes performed better under simulated drought stress than the BL variety with higher yield potential (> 125 ton ha⁻¹). These mutants differed from their original cultivar in the leaf sheath, internode, stem, and bud, hairy, and adherence-leaf sheath characters. Shortly, further evaluation of agronomical performances will be made on the first and second ratoon.

Keywords: mutation, field selection, dryland, yield

1. Introduction
In Indonesia, sugarcane development on optimal land has been facing very high competition with food crops. Due to this reason, sugarcane development on optimal lands continues to decrease. To maintain national sugarcane production, sugarcane development programs have been shifted to sub-optimal lands such as rainfed land, which are often experiencing drought stress, resulting in low sugarcane productivity [1-4]. To support the development program in rainfed areas, varieties that tolerate limited water conditions are needed. Currently, sugarcane varieties that tolerate drought stress are limited. Therefore, a breeding program to develop biotic stress is being attempted.

A mutation breeding scheme is one of the tools to develop a new variety. Mutations cause changes in various characters, including morphology [5], physiology [6], and agronomy [7-8], resulting in mutants with new characters that are different from the original cultivars. Some of the changes are positive and useful in breeding programs, such as increased plant height and cane yield [9]. However, the negative ones do occur, such as a decrease in plant height and diameter [7] or the number of leaves...
and fruit [10] that the breeder does not desire. Hence, it is necessary to develop a method to select the mutants that suit breeders' needs.

Mutation breeding can be combined with in-vitro selection [11]. High-yielding and stable varieties but sensitive to biotic or abiotic stresses are generally used for breeding material [6]. The mutations were then carried out, followed by in vitro selection in the laboratory using PEG 6000, either one time or more [11-13]. Later, mutants that have successfully passed in vitro selection have to be assessed their agro-morphological performances under field conditions. Several research results reported changes in the characters of the sugarcanes' leaf sheath, stem, internodes, and bud [14], stomata [15], plant height, stem diameter, and leaf area [7].

An experimental garden with a dry climate and controlled irrigation facilities is suitable for selecting drought-stress candidate plants. The selection of drought in sugarcane must be considering sugarcane needs at each of the four growth phases, namely germination (5-30 days), sprouting (6-12 weeks), stem elongation (4-10 months), and maturity (>8 months). The availability of sufficient water during the germination phase can accelerate the growth of shoots and roots and increase the number of tillers in the budding phase. Further, the level of water availability during the stem elongation period strongly determines the stem height, and hence the yield level [16].

In testing sugarcane plants for drought tolerance, the appropriate time for drought stress treatment is crucial, i.e., during the stem elongation period (approximately after the plant is four months old). The duration of treatment is according to conditions. Breeders can identify plants that tolerate water-limited conditions by comparing plant growth between genotypes under simulated drought stress conditions. The purpose of this study was to select sugarcane mutants that were tolerant to a drought stress condition based on morphological and agronomic characters.

2. Materials and methods
2.1. Research materials, location and time
The materials used in this study were 27 selected mutant genotypes of sugarcane along with their original cultivar (BL variety). These mutants were obtained from physical mutation using gamma-ray irradiation at a 5 - 35 gray dose followed by in vitro selection in a tissue culture laboratory conducted in 2018 using the selection agent PEG 6000 and preliminary evaluation in the greenhouse. The field location was at Installation of Research and Assessment of Agricultural Technology Asembagus, Situbondo, East Java, on dryland with dry climates with 8-9 dry months per year. The planting time was in January 2019.

2.2. Experimental design and research method
The experimental design was a Randomised Complete Block Design, repeated three times. The treatment unit size was a plot consisting of 2 rows of 3 m long. The Good Agricultural Practice (GAP) for sugarcane cultivation, according to [17], is a methodology for maintenance of sugarcane, except for irrigation. Stress conditions are imposed at four months old plants for two months until 50% of the population wilts. Then, the plants were re-irrigated as needed.

2.3. Selection based on morphological and agronomical characters
Observations were made on morphological [18-19] and agronomic characters. The agronomic characters included stem length, stem diameter, internode, stem weight, cane yield, and Brix was on a ten-month-old plant. Selected mutants were those that were better than their original cultivar with appropriate morphological character.

2.4. Data analysis
The PBSTAT-CL 2.1.1 is the program to analyze the dissimilarity between mutant and the original cultivar using morphological data. ANOVA and Duncan's Test with SAS program at 5% level is the statistical method to analyze agronomic data.
3. Result and discussion

3.1. Morphological characters of sugarcane drought-tolerant mutants compared to the original cultivar

The evaluation results on 34 morphological characters showed that all sugarcane mutants had changed to their original cultivar or parent (BL) in one or more characters. There are two significant clusters based on morphological characters, with 50% of dissimilarity. The range of dissimilarity between mutant and the original cultivar is 30 – 50%. Cluster I consisted of 23 mutants, while cluster II consisted of 4 mutants. Two sub-clusters of cluster I, namely subclusters II.1 and II.2, and two sub-subclusters for each, namely sub-subclusters II.1.1 and II.1.2. The original cultivar (parent) of the BL variety was in sub-subcluster II.1.1 along with 16 other mutants and separated from other mutants in sub-subcluster II.1.2 (Figure 1). The difference between clusters I and II are in the character of the hairs on the leaf sheath. Mutants in cluster I had hairs on their leaf sheaths, while in cluster II all mutants had no hairs on their leaf sheaths (Table 1).

Two out of 34 characters are monomorphic, i.e. the cross-section and shape of internode, 15 are dimorphic, and 17 are polymorphic. Mutant number 21, separated from all mutants, was characterized by a relatively large number of cracks in the stem, whereas in BL mutants and their original cultivar, there was little or none. Besides that, mutant number 21 also has a leaf sheath character that is difficult to remove, while other mutants have easy removal. Sub-subgroup II.1.1 and II.1.2 distinguished by the character of the width of the dorsal hair area on the leaf sheath, sub-group II.1.1. have dorsal hair area ≥ 1/4 leaf sheath width, while group II.1.2 ≤ 1/4 leaf sheath width (Table 1).

3.2. Agronomic characters

The agronomic performance of the mutants varied in several characters. Several mutants had no significant difference in agronomic characteristics compared to the original cultivar (BL), while others had lower or higher characters. A total of nine mutants had stems that were longer than the BL, namely mutants numbered 1, 2, 3, 16, 17, 18, 22, 26, and 27. A total of five mutants had more segments, namely mutants numbered 1, 2, 8, 9, and 10. The other three mutants had poor growth with very short stems, relatively small stem diameter, few internodes, and very short internodes, namely mutants 19, 21, and 24 (Table 2).

Figure 1. Sugarcane mutants distribution based on cluster analysis of 34 morphological characters.
### Table 1. The morphological characters of the 27 mutant sugarcane genotypes compare to the original cultivar (P).

| Morphological Marker | Code | Description | Original cultivar (P) and mutant genotypes |
|----------------------|------|-------------|-------------------------------------------|
| **Leaf Character**    |      |             |                                           |
| Curvature (D1)        | 1    | Curved Tips | P All mutants except number 27            |
|                      | 2    | Arched or curve at the base | 27 |
| Auricle (D2)         | 1    | Absent      | P 1,2,3,4,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,24,27 |
|                      | 2    | Present, weak and small (length < three widths) | 5,6,20,23,25,26 |
|                      | 3    | Present, solid and large (length ≥ three widths) | 21,24,25,26 |
| Auricle standing (D3) | 1    | Straight    | P 1,4,11,12,14,15,16,17,22,24             |
|                      | 2    | Oblique     | 2,3,5,6,7,8,9,10,13,18,19,20,21,23,25,26,27 |
|                      | 3    | Absent      |                                           |
| Leaf colour (D4)      | 1    | Dark Green  | P 1,2,3,4,5,6,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,22, |
|                      | 2    | Green       | 3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,22, |
|                      | 3    | Yellowish Green | 4,8,9,13,21,27 |
| Dewlap colour (D5)    | 1    | White       | P 15,16                                      |
|                      | 2    | Purple      | P 1,2,3,4,5,6,8,9,10,11,12,13,14,15,17,18,19,20,21,22,22,3,24,25,26, |
|                      | 3    | Green       | 7,27                                        |
| Leaf width (D6)       | 1    | Narrow (< 4cm) | P 2,4,7,8,9,15,19,21,24 |
|                      | 2    | Medium (4-5 Cm) | 1,3,6,10,11,12,13,14,16,17,23,26          |
|                      | 3    | Wide (> 5 Cm) | 5,18,20,22,25,27                          |
| **Leaf-sheath characters** |      |             |                                           |
| Dorsal hairy width (P1) | 1    | Absent      | P 4,7,8,9                                    |
|                      | 2    | < 1/4 Blade width | 10,11,12,15,18 |
|                      | 3    | ≥ 1/4 Blade width | P 1,2,3,5,6,13,14,16,17,19,20,21,22,23,24,25,26,27 |
| Dorsal Hairy position to the tips (P2) | 1    | Absent      | P 4,7,8,9                                    |
|                      | 2    | < 1 Cm       | 10,11,12,13,15,18                          |
|                      | 3    | > 1 Cm       | P 1,2,3,5,6,13,14,16,17,19,20,21,22,23,24,25,26,27 |
| Dorsal hairy length (P3) | 1    | Absent      | P 4,7,8,9                                    |
|                      | 2    | < 2 Mm       | 11,12,13,15,18                              |
|                      | 3    | > 2 Mm       | P 1,2,3,5,6,10,14,16,17,19,20,21,22,24,25,26,27 |
| Dorsal hairy standing (P4) | 1    | Absent      | P 4,7,8,9                                    |
|                      | 2    | Straight     | 1,6,13,16,17,26,27                          |
|                      | 3    | Oblique      | P 5,14,15,22,24                             |
|                      | 4    | Horizontal   | P 2,3,10,11,12,18,19,20,21,23               |
| Dorsal hairy density (P5) | 1    | Absent      | P 4,7,8,9                                    |
|                      | 2    | Sparse (<75/Cm2) | 10,11,12,15,18,23 |
|                      | 3    | Dense (≥ 75 Cm2) | P 1,2,3,5,6,13,14,16,17,19,20,21,22,24,25,26,27 |
| Edge hairy (P6)       | 1    | Absent      | P 1,3,4,5,7,8,9,10,11,12,15,16,18,19,20,21,22,23, |
|                      | 2    | Present     | 2,6,13,14,17,24,27                           |
| Adherence of leaf sheath (P7) | 1    | Strong      | P 4,21                                        |
|                      | 2    | Medium      | 8,9,10,12,14,19,20,21                        |
|                      | 3    | Weak        | P 7,11                                        |
| Waxiness (P8)         | 1    | Absent      | P 2,4,7,8,9                                    |
|                      | 2    | Weak        | 10,11,12,15,16,17,18,22,23,25,26,27          |
| Colour (P9)           | 1    | Purple      | P 2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23, |
|                      | 2    | Purplish green | 2,4,7,8,9                                    |
|                      | 3    | Green       | 25,26,27                                      |
### Internode characters

| Character                  | 1 | 2 |
|----------------------------|---|---|
| Zig-zag alignment (R1)     | Absent or very weak | Strong |
| Cross-section (R2)         | Circular | Oval |
| Shape (R3)                | Cylindrical | Conoidal |
|                            | Bobbin-Shape | Tumescent |
| Length (R4)               | Long (>15 cm) | Medium (13-15 cm) |
|                            | Short (<13 cm) |  |
| Crack (R5)                | Absent | Present in part of internode | Present in all internode |

### Stem characters

| Character                  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|----------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Primordial root (B1)       | < 2 Lines | 2-3 Lines | > 3 Lines |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Primordial root upper bud (B2) | Absent | Present |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Colour (B3)                | White | Green | Purple | Yellow | Red | Yellowish-Green | Greenish-Yellow | Purplish-Green | Yellowish-White (Albino) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Diameter (B4)              | Thick (>3 cm) | Medium (2.5-3 cm) | Thin (<2.5 cm) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Waxiness (B5)              | Absent | Weak | Medium | Strong |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Crack (B6)                 | Absent | Rarely | Many |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

### Bud characters

| Character                  | 1 | 2 |
|----------------------------|---|---|
| Bud wings (M1)             | Above bud | Other |
| Width of bud-wing (M2)     | Absent | Wide base to top |
| Edge of bud wing (M3)      | Flat | Serrated |
| Position of bud tip (M4)   | Under/on the center of the bud | Above of bud centre |
| Edge base bud hair (M5)    | Absent | Present |

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5
| Genotype Type | Stem length (cm) | Stem diameter (mm) | Nos of internode | Internode length (cm) | Stem weight per m (kg m⁻¹) | Yield per ha (ton ha⁻¹) | Brix (%) |
|---------------|------------------|-------------------|------------------|----------------------|---------------------------|------------------------|---------|
| 1             | 189.10 a-c       | 26.82 a-d         | 23.13 abc        | 13.71 ab             | 1.42 cde                  | 0.75 b-f               | 113.49 cde | 16.20 f-k |
| 1             | 189.10 a-c       | 26.35 a-e         | 23.00 abc         | 13.35 abc            | 2.14 a                    | 1.10 a                 | 171.11 a  | 16.90 c-i  |
| 2             | 182.30 a-e       | 27.22 a-e         | 20.93 a-c         | 12.99 abc            | 1.43 cde                  | 0.79 b-f               | 114.01 cde | 18.07 a-e  |
| 3             | 152.23 d-i       | 19.79 ef          | 19.63 b-g         | 9.78 de              | 1.17 c-h                  | 0.78 b-f               | 93.56 c-h  | 13.73 i    |
| 4             | 160.63 b-i       | 27.63 abc         | 19.47 b-g         | 13.01 abc            | 1.24 c-h                  | 0.78 b-f               | 99.30 c-h  | 17.97 a-e  |
| 5             | 167.73 a-i       | 28.10 abc         | 20.90 a-e         | 12.07 a-d            | 1.43 cde                  | 0.85 bcd               | 114.70 cde | 17.67 b-f  |
| 6             | 139.03 h-j       | 30.53 ab          | 21.30 a-d         | 9.34 de              | 0.93 hij                  | 0.65 c-g               | 72.22 hij  | 16.13 f-k  |
| 7             | 160.23 b-i       | 19.74 f           | 23.47 ab          | 10.54 cd             | 1.38 c-f                  | 0.86 bcd               | 110.28 c-f | 15.83 h-k  |
| 8             | 147.50 e-i       | 19.39 f           | 23.40 ab          | 11.22 a-d            | 1.06 e-i                  | 0.72 b-f               | 84.98 e-i  | 16.00 g-k  |
| 9             | 181.17 a-f       | 24.20 a-f         | 24.00 a           | 11.57 a-d            | 1.37 c-f                  | 0.75 b-f               | 109.85 c-f | 17.63 b-f  |
| 10            | 173.53 a-h       | 24.16 a-f         | 15.80 gh          | 11.82 a-d            | 1.18 c-h                  | 0.68 c-g               | 94.53 c-h  | 15.63 ijk  |
| 11            | 172.07 a-h       | 25.16 a-f         | 20.57 a-f         | 12.88 abc            | 1.26 c-h                  | 0.73 f-b               | 100.83 c-h | 17.50 b-g  |
| 12            | 176.90 a-g       | 23.50 b-f         | 20.87 a-e         | 11.79 a-d            | 1.24 c-h                  | 0.70 c-g               | 98.97 c-h  | 16.83 d-j  |
| 13            | 140.93 g-i       | 31.35 a           | 16.37 fgh         | 11.01 bcd            | 0.95 g-j                  | 0.69 c-g               | 75.69 g-j  | 15.33 jk   |
| 14            | 133.10 j         | 18.35 f           | 18.27 d-h         | 9.78 de              | 1.11 d-h                  | 0.83 b-e               | 88.84 d-h  | 15.67 iji  |
| 15            | 185.50 a-d       | 26.41 a-e         | 19.93 a-g         | 14.16 a              | 1.49 bcd                  | 0.80 b-f               | 119.00 bcd | 17.43 b-g  |
| 16            | 119.07 a         | 28.88 abc         | 22.03 a-d         | 11.86 a-d            | 1.52 bc                   | 0.77 b-f               | 121.90 bcd | 16.60 e-j  |
| 17            | 194.63 ab        | 29.58 abc         | 20.07 a-g         | 13.02 abc            | 1.83 ab                   | 0.96 ab                | 146.66 ab  | 18.00 a-e  |
| 18            | 107.83 j         | 18.38 f           | 15.17 h           | 5.61 f               | 0.64 jk                   | 0.61 d-g               | 51.48 jk   | 17.00 c-i  |
| 19            | 173.90 a-h       | 30.68 ab          | 20.47 a-f         | 9.63 de              | 1.26 c-h                  | 0.74 f-b               | 100.92 c-h | 16.87 c-i  |
| 20            | 174.43 a-h       | 30.14 ab          | 20.83 a-e         | 11.18 a-d            | 1.32 c-g                  | 0.75 f-b               | 105.99 c-g  | 18.17 a-d  |
| 21            | 95.80 l          | 20.22 def         | 16.27 fgh         | 7.62 ef              | 0.41 k                    | 0.47 g                 | 33.36 k    | 18.83 kl   |
| 22            | 170.37 a-h       | 29.57 abc         | 20.03 a-g         | 11.61 a-d            | 1.30 c-h                  | 0.77 b-f               | 104.31 c-h  | 18.40 abc  |
| 23            | 183.17 a-e       | 30.09 ab          | 21.17 a-d         | 11.66 a-d            | 1.58 b                    | 0.87 b-c               | 126.48 bc  | 16.30 f-k  |
| 24            | 193.97 ab        | 28.63 abc         | 19.40 b-g         | 12.84 abc            | 1.48 b-e                  | 0.76 b-f               | 118.21 b-e  | 16.93 c-i  |
| 25            | 145.67 F-i       | 26.98 a-d         | 18.50 d-h         | 13.43 abc            | 1.21 c-h                  | 0.82 b-e               | 96.67 c-h  | 18.57 ab   |

Note: Numbers with the same letters in the same column are not significantly different in 5% of Duncan test.

Table 2. Agronomic performance of 27 sugarcane mutant genotypes and the original cultivar (BL) in dryland Aseambahus.
Three mutants, i.e., numbers 2, 18, and 26, showed better agronomic potential in dryland conditions than the other cultivars, with higher weights per stem and stem weights per meter than the original cultivar. These three mutants also had higher production per hectare. Mutants 2 and 26 are in the same cluster as the BL in sub-cluster II.1.1, while 18 is in sub-cluster II.1.2. Despite being in the same cluster, these mutants were still distinguishable from the BL. The number 2 mutant had narrower leaves than the original cultivar, the horizontal of dorsal hairy standing, absence of zig-zag alignment, longer internodes and thinner stem diameter than the original cultivar, the medium of waxiness, and the triangular bud. In the number 26, the mutant had a solid and large auricle with an oblique position, medium leaf width, straight dorsal hairy standing, medium internodes, purplish-green stem color, and medium of waxiness, and absence of bud hair. The number 18 mutant has shorter dorsal hairs, a horizontal position, bright red stem color, thick diameter, no stem cracks, and triangular bud. The similarities between the three mutants with the original cultivars are their erect leaf with curved curvature leaf, dorsal hair, and a weak leaf sheath adherence like the BL (Table 1).

Mutant number 19, which had a poor agronomic appearance, became morphologically close to the mutant number 18. The similar in mutant number 24, which had close morphological characters to mutant number 2 (Figure 1). The similarity in morphological characters did not guarantee closeness in agronomic performance. Mutant numbers 2 and 18 had more internodes and were longer than mutants 19 and 24 (Table 2).

3.3. Selection based on morphological characters

The selection of drought-tolerant sugarcane must consider the beneficial characteristics of plants. The selection must also consider the needs of breeders, farmers, and sugar mills as users. The selected mutants are those with appropriate morphological character.

Morphological character is one of the genotype markers that can distinguish one from other genotypes. The marker used in this study is the same as [20], who reported that 22 of the 23 morphological characters evaluated in several locations were not significantly different, which indicates that the morphological characters are stable and can identify a genotype in different locations. These characters include the character of leaf, leaf sheath, internode, and stem.

The clustering of genotypes based on morphology makes it easier for breeders to choose mutants with similarities or dissimilarities than original cultivars or between mutants. With clustering, it will be easier to choose mutants with certain desired characters. Clustering can determine genotypes that have unique characters and are different from others to characterize these varieties. Qualitative characters are stem color, stem thickness, cracks in the internodes, wax layer, internode structure, roots, leaf color, leaf sheath color, hair on leaf sheath, stem color, thick diameter, leaf length and width, leaf surface width [20].

The clustering depends on the evaluated genotype. In this study, there are two significant clusters with 50% dissimilarity divided into several sub-clusters. This result is different from the 105 genotypes of [21], dividing sugarcane into 15 clusters with a degree of similarity of 60% (dissimilarity 40%), and the auricle character contributed the most to the total diversity.

Polymorphic characters can distinguish the genotype. Mutant number 21, separated from other mutants, was the only mutant with stem cracks in all stem segments. Meanwhile, mutants number 10, 15, and 21, each separated from their group, turned out to have round buds, different from the group's character. Clusters can trace mutants that do not have hair on the leaf sheath or mutants that have hair. Likewise, it is easy to choose mutants that are weak of adherence to leaf sheath or those that are strong. Evaluation of ten sugarcane genotypes based on 27 morphological characters showed that one character was monomorphic, which same in all varieties, namely the character of the width of the root path, fourteen were dimorph, and the other 12 were polymorphic [22].

Some essential characters in sugarcane are erect leaves with curved tips, weak leaf sheath adherence, hairs on leaf sheath, large stem diameter, and long internodes. Erect leaves and hairs on the dorsal leaf
sheath are closely related to resistance to pests. Stem diameter and internode length correlated with crop production [7]. Due to weak leaf sheath adherence, the easily detached leaf sheath facilitates farmers’ and sugar mills’ harvesting process and favours. Although not widely reported, each morphological character certainly has benefits for the plant itself, as well as for animals and humans. Sugarcane leaves and shoots are suitable as animal feed and biofuel [23]. Thus, the soft leaves can be a consideration in selecting new varieties of sugarcane. Other research was studied to find a correlation between morphological characters and resistance to biotic and abiotic stresses and production ability. Leaf area can indicate the sugarcane that is drought-tolerant [24].

The qualitative morphological characters were very influential on the disease infestation of Chilo infuscatusellus [25]. The essential characters include plant girth, leaf area, leaf sheath hairiness, and leaf thickness. These morphology and qualitative characters of sugarcane can avoid stem borer attacks on sugarcane.

Sugarcane with easily detached leaf sheaths showed minor sugarcane-scale attacks than those with tightly attached leaves. There is a relationship between morphological characters and pest tolerance [26]. Of the 20 varieties they evaluated, the morphology of sugarcane that was potentially tolerant to pests was cylindrical stem, moderate stem border, strong waxiness, dense dorsal hairs, and strong leaf sheath adherence 475 SOFF variety.

Sugarcane stem borer prefers a genotype with bright green leaves and drooping leaves than sugarcane with erect leaves. Leaf size correlated with borer attack; short and broad leaves provide more borer pests than sugarcane with longer and narrower leaves. The hardness of the leaf sheath is also a factor. Sugarcanes more tolerant of stem borer pests have darker, long, narrow, erect leaves, tough leaf sheaths, and longer spindles [27].

3.4. Selection based on agronomic characters

The mutants selected were those with high production potential. Stem length is one of the characters that can indicate the tolerant sugarcane to drought stress [28] and correlates with sugar yield [7, 29]. This character also has broad heritability [31] and hence can be used as one of the selection criteria in the breeding program.

Mutants number 2, 18, and 26 have stems longer than the original cultivar. Those three mutants also have a large diameter, many internode numbers, and heavy stems. Although the original BL cultivar is one of the recommended varieties for development in dryland [32], those three mutants evaluated have better growth than the BL. Those three mutants also have morphological characters that are beneficial to plants and favoured by farmers.

The environment strongly influences the results of sugar cane. Besides that, the results of sugar cane in the first plant can be different from the second or third plant. There are stable varieties every year, but some have decreased in the second plant and so on. The data from the first and second ratoon are still needed to complete the data.

4. Conclusion

Three mutant genotypes, namely mutant numbers 2, 18, and 26, showed better tolerance to drought stress than their original cultivar based on agronomic appearance with higher stem elongation, heavier stem, and higher yield per hectare. The yield of the three mutant genotypes was 171.11, 146.66, and 126.48 tons per hectare, respectively. These yield potentials are higher than the original variety BL, which was only 96.67 tons per hectare. The three mutants differed from the original variety in several morphological characters. However, they had similar essential characters: relatively erect leaves with curved curvature leaf, weak adherence leaf sheath, and hairy leaf sheath. Further evaluation is needed from the second and third plants to complete the data.
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