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Research Article

Yield component evaluation of mutated sugarcane at first and ratooning plantations

Fimas Ariyanto [1], Mohammad Ubaidillah [2], and Sri Hartatik [2,*]

[1] Department of Agronomy, Faculty of Agriculture, University of Jember, 37 Kalimantan St. Sumbersari, Jember 68121, East Java, INDONESIA
[2] Department of Agronomy, Faculty of Agriculture, University of Jember, 37 Kalimantan St. Sumbersari, Jember 68121, East Java, INDONESIA
* Corresponding author (✉ srihartatik1@yahoo.com)

ABSTRACT

Increasing national sugar production can be done by developing new varieties of sugarcane varieties with high potential yields. To ensure profitability and sustainability, however, the new varieties should be accompanied by data on their ratooning ability. This study aimed to evaluate the stability of the yield component of ratooning sugarcane resulting from mutations. The experiment was arranged using a factorial randomized complete block design with the first factor being four genotypes of sugarcane (G) consisting of three mutant genotypes with codes M3.2, M3.3, M3.4 and one original Bululawang genotype (BL). The second factor was ratooning (K) which consisted of three levels, namely first plant (TP), first ratoon (TK1) and second ratoon (TK2). The combination of treatments was repeated 4 times so that 48 unit combinations were obtained. One unit consisted of 28 cane clumps divided into 4 rows. The results showed that the ratooning factor had a significant impact on the value of the proportion of sucrose produced by the mutant sugar cane genotype. The ratooning ability of mutant genotypes to produce sucrose was recorded above 75%. All genotypes of mutant had superior characters compared to non-mutant based on stalk weight and percentage of sucrose.

Keywords: Bululawang, morphology, mutant, ratoon, sugar

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INTRODUCTION

Increasing national sugar production can be done by developing new superior sugarcane varieties with high yield values. The development of varieties to obtain superior criteria can be done by mutation breeding. The purpose of mutation breeding in plants is to obtain genetic diversity and new superior traits (Setiawan et al., 2015).

In the present study, the development of new superior sugarcane genotypes through mutation breeding was carried out in 2016, on the Bululawang sugarcane variety using EMS mutagen at a concentration of 16 mM with induction times of 5 hours and 10 hours. Based on this research, three mutant sugarcane genotypes were produced, namely M2, M3 and M4 with sugar yield potential of 18.58, 16.58 and 15.57 percent respectively through laboratory scale measurements. The potential yield value of new sugarcane genotypes is above the potential yield of the original Bululawang variety (10.81 percent).

In the releasing process of a new variety, Indonesian researcher follows the Regulation in Minister of Agriculture No. 37 of 2006, on the Release of Varieties Chapter II Article 4. The regulation states that the results of domestic plant breeding or introduction proposed for releasing new varieties must go through adaptation tests for annual crops or observation tests for perennial crops. Observation tests on new varieties are conducted to prove their superiority. One of the observation tests that must be carried out on the procedure of releasing new varieties, especially sugarcane, is the stability of yield components including stalk length, internode length, internode number, stalk diameter, number of tillers, stalk weight per meter of row and yield.

Superior sugarcane is characterized by superior properties, one of which is the ratooning ability. Ratooning sugarcane is plant regrowth after harvest, and then it is maintained such as fertilizer application and becomes the next harvest. The various characteristics that will be shown by ratooning sugarcane can be attributed to the sugarcane production ability (Mehareb & Galal, 2018).

The genotypes that will become candidates of new varieties must at least undergo several ratooning tests to evaluate the stability of productivity and yield. There are several rules of ratoon as compared to first harvesting crops, such as ratooning sugarcane produces lower sucrose when compared to the first crop (Nurhidayati et al., 2013), and optimum ratoon is up to three times (Kadarwati et al., 2015). The ability of ratooning is the most important economic consideration before the variety is released as a commercial variety.

In general, the ratoon of sugarcane has different physiological and morphological characteristics from the first crop. Therefore, the evaluation of biometric characteristics is used to observe the stability of ratoon growth (Junior et al., 2018). Some biometric characteristics that are commonly used are number of tillers, stalk diameter and the number of internodes (Bezerra et al., 2017). Such biometrics characters correlate directly with yield, which means that superior biometric characteristics imply high sucrose accumulation in the sugarcane. Here, high sucrose content is a desirable component in sugarcane stalks (Shikanda et al., 2017), and its stability such as 1st and 2nd ratooning plantations determines the superiority. This study aimed to evaluate the stability of the yield component of ratooning sugarcane resulting from mutations.

MATERIALS AND METHODS

Research site

The research was conducted from October 2020 - December 2021 at a farmer field in Arjasa Village, Jember Regency, East Java, Indonesia. Laboratory analysis was carried out at the Plant Breeding Laboratory, Agrotechnology Laboratory and Plant Analysis Laboratory, Faculty of Agriculture, University of Jember.

Research design

The experiment was arranged using a factorial randomized complete block design. The first factor was four of 3rd generation sugarcane genotypes (G): three mutant genotypes coded M3.2 (18.58% yield potential), M3.3 (16.58% yield potential), M3.4 (15.57% yield potential) and one original Bululawang genotype (BL) with 10.81% yield potential. The second factor was ratooning (TK) consisting of 3 levels: first plant (TP), first ratoon (TK1) and second ratoon (TK2). Repetition was done 4 times so that 48 unit plots were obtained. One unit plot consisted of 28 sugarcane clumps divided into 4 rows. The distance between the rows was 1 m and the distance between clumps in the row was 0.4 m. The effective row length of each experimental plot was 11.2 m (4 m x 2.8 m), so in one meter of row on average contained 2.5 sugarcane clumps.

TP was the sugarcane used in the second multilocation test which data was taken in 2021. TK1 was obtained from the results of the sugarcane used in the first multilocation test which was completed in 2020, so the first ratoon data was taken in 2021. The second crop of Bululawang mutant was also ratooned in the same season, so its regrowth was referred to as TK2 and data were also taken in 2021.

Fertilizers application in TP was done using KCl (60% K_2O) at a dose of 200 kg ha^{-1}, while ZA and SP-36 fertilizers were 700 kg ha^{-1} and 200 kg ha^{-1}, respectively. The fertilizer application followed the recommended dose by the government sugar factory (PG-BUMN). Fertilizer application was done twice, i.e., at the beginning of planting as much as 1/3 dose of ZA, all doses of SP-36 and 1/3 dose of KCl. The second application was done at 60-75 DAP (Days After Planting) with the remaining dose of each fertilizer.

Fertilization doses at TK1 and TK2 were given according to PG-BUMN recommendations. Fertilizer application was done twice, i.e., at 30 days after ratooned as much as 1/2 dose of ZA (400 kg ha^{-1}) and all doses of SP-36 (200 kg ha^{-1}). The second application was done at 60 - 75 days after ratooned with the remaining dose of ZA (400 kg ha^{-1}) and all doses of KCl (200 kg ha^{-1}).

Observations

Morphological observation included stalk diameter, internode length, number of internodes, stalk length, and number of tillers. Biochemical observations included reducing sugar content, stalk yield, and percentage of ratooning ability.

Observations and data collection were done at harvesting age. The harvesting age in this experiment should have been done when the sugarcane was 10 to 12 months old. However, excess rainfall at designed harvesting time delayed harvest until 14 months. Excess rainfall during the sugarcane ripening phase causes lower sucrose content (Riajaya et al., 2016). Data were analyzed using analysis of variance and further tests were done using Duncan Multiple Range Test (DMRT).

Morphological characters were observed directly at harvest, while observations on sucrose content were made by calculating the ratio between the sucrose content obtained after the extraction process and the weight of the sample used in the laboratory. The sucrose content obtained was then used for calculating the ratooning ability. Calculation of the percentage of sugarcane ratooning ability is done using the formula (Abu-Ellail et al., 2019) as follows :

$$KK\ (\%) = (100 \times TK2)/TP$$

Note: KK=ratooning ability; TK2=second ratoon; TP=first ratoon

RESULTS AND DISCUSSION

Analysis of variance

The results of the variance analysis show that there was no significant interaction effect between sugarcane genotype (M) and ratooning sugarcane type (K) on all observation variables (Table 1). Genetic variation in each sugarcane genotype mutation occurs randomly and will determine the yield potential (Purnamaningsih & Hutami, 2016). Sugarcane variety shows different characteristics and produces different yields depending on its genetic capabilities (Windiyani & Mahfut, 2021).

Table 1. Summary of genotypes and ratooning effects on sugarcane.

Variable	G	K	GxK
Stalk length (m)	**	ns	ns
Internode length (cm)	ns	ns	ns
Number of internodes	**	ns	ns
Stalk diameter (cm)	**	**	ns
Number of tillers (stalk)	**	ns	ns
Stalk weight per m *juring* (kg)	**	ns	ns
Sucrose content (%)	**	**	ns
Stalk reduction (%)	ns	ns	ns

Note: G = genotype, K = ratoon, GxK = interaction of genotype and ratoon, ** = highly significant effect, ns = no significant effect.

Morphological characters

Stalk length of all mutant genotypes was significantly different from the original Bululawang (BL) (Table 2). Genotypes M3.2 and M3.4 in the first crop (TP) and all mutant genotypes in the first ratoon (TK1) and second ratoon (TK2) were not significant. Stalk length was significantly affected by sugarcane variety (Abu-Ellail et al., 2019).

The number of internodes of BL sugarcane in TK1 and TK2 was 21.50 and 20.00, respectively; these results were significantly different from all mutant genotypes (Table 2). Number of internodes in sugarcane stalks is the best predictor for strong ratooning ability and yield (Abu-Ellail et al., 2019). In the present experiment, mutant genotypes exhibited greater internode numbers, meaning that those genotypes had a larger ability in ratoon production and yield. Mutated sugarcane has undergone genetic changes and may have a new variation (Weksanthia et al., 2021), therefore, mutant genotypes might have more active cell division than the wild type.

Table 2. Effect of mutated sugarcane genotypes on stalk length (m), internode number (internodes), stalk diameter (cm), stalk weight (kg) and sucrose (%) in all types of ratooning.

Ratooning (K)	Characteristics	Genotype (G)				Average
		BL	M3.2	M3.3	M3.4	
First Plant (TP)	Stalk length (m)	2.46c	2.82a	2.58bc	2.78ab	2.66
	Internode length (cm)	14.68ns	16.55ns	14.95ns	15.78ns	15.49
	Number of internodes	23.25a	23.75a	24.00a	24.00a	23.75
	Number of tillers (stalk)	9.59c	11.75a	10.31bc	11.00ab	10.66
	Stalk weight/meter row (kg)	6.81a	7.56a	7.00a	7.13a	7.13
First Ratoon (TK1)	Stalk length (m)	2.29b	2.95a	2.90a	2.85a	2.75
	Internode length (cm)	12.53ns	14.45ns	12.78ns	12.28ns	13.01
	Number of internodes	21.50b	27.25a	26.00a	24.75a	24.87
	Stalk weight/meter row (kg)	10.00c	12.00ab	12.25a	10.75bc	11.25
	Stalk length (m)	5.79b	7.44a	6.89a	7.00a	6.78
Second Ratoon (TK2)	Stalk length (m)	2.28b	2.95a	2.89a	2.83a	2.74
	Internode length (cm)	11.90ns	12.25ns	12.55ns	12.03ns	12.18
	Number of internodes	20.00b	26.25a	25.00a	24.25a	23.87
	Stalk weight/meter row (kg)	9.25b	11.25a	10.75a	10.50a	10.44
	Stalk length (m)	5.57b	7.13a	6.80a	6.91a	6.60

Note: BL = original Bululawang yield potential of 10.81%, M3.2 = mutant yield potential of 18.58%, M3.3 = mutant yield potential of 16.58%, M3.4 = mutant yield potential of 15.57%, ns = no significant effect. Numbers in the same row followed by the same letter are not significantly different at 5% DMRT test.

Genotype M3.2 recorded the highest number of tillers compared to other genotypes in TP, but was not significantly different from M3.4 (Table 2). Genotypes M3.2 and M3.3 in TK1 and all mutant sugarcane genotypes in TK2 showed no significantly different, but it was significantly different from the BL genotype. The varieties with strong ratooning ability have low stalk mortality, short rootstock internode length and effective tillering (Wei et al., 2017). Optimizing sugar production per unit area with strong ratooning ability is among the final goals of breeding (Xu et al., 2021).

The number of tillers formed in a sugarcane clump will affect its growth rate including the average stalk weight. All genotypes evaluated in TP and all mutant genotypes in TK1 and TK2 showed no significantly different in stalk weight per meter of row, but mutant genotypes showed significantly different to BL in TK 1 and TK 2 (Table 2). The average stalk weight showed that the accumulation of sucrose in mutant sugarcane could be greater than non-mutant. Accumulation of sucrose in sugarcane starts in line with the elongation process, namely located in the internodes, and the accumulation continues until the elongation process terminated (Thirugnanasambandam et al., 2017).

Stalk diameter and sucrose content

M3.2 genotype showed the largest stalk diameter at TP and TK1 with values of 3.41 cm and 3.10 cm (Table 3). When the number of internodes is less and the stalk length is relatively short, the stalk diameter will be greater (Djumali et al., 2019). It is noted that the stalk diameter of M3.2 and M3.3 genotypes at TK2 were not significantly different. M3.2 genotype also recorded a decrease in diameter at the second ratoon with a value of 2.33 cm and significantly different from the first crop and the first ratoon (Table 3).

Morphological characteristics such as the size of the stalk diameter formed in sugarcane are closely related to the ability of ratooning sugarcane (Wei et al., 2017).

Table 3. Ratooning and genotypes effect on stalk and sucrose content (%) in sugarcane.

Genotype (G)	Characters	Ratooning (K)			Average
		TP	TK1	TK2	
Bululawang (BL)	Stalk diameter (cm)	2.94a	2.53b	2.53b	2.66
	Sucrose content (%)	9.86a	7.13b	6.87b	7.95
Mutant 2 (M3.2)	Stalk diameter (cm)	3.41a	3.10b	2.83c	3.11
	Sucrose content (%)	11.14a	9.12b	8.99b	9.75
Mutant 3 (M3.3)	Stalk diameter (cm)	3.14a	2.85b	2.78b	2.92
	Sucrose content (%)	10.56a	9.11b	8.80b	9.49
Mutant 4 (M3.4)	Stalk diameter (cm)	3.20a	2.78b	2.60b	2.86
	Sucrose content (%)	11.37a	8.85b	8.68b	9.63

Note: BL = original Bululawang yield potential 10.81%; M3.2 = mutant yield potential 18.58%; M3.3 = mutant yield potential 16.58%; M3.4 = mutant yield potential 15.57%; TP = first crop; TK1 = first ratoon; TK2 = second ratoon; Numbers in the same row followed by the same letter are not significantly different at 5% DMRT test.

The sucrose content produced by BL sugarcane in TK 1 and TK 2 was 7.13% and 6.87%, respectively (Table 3). The results were significantly different from all mutant sugarcane genotypes. Heavier sugarcane stalks are assumed to store more sucrose (Antika & Ingesti, 2020). The results of the analysis test between the factors of genotype and variety of sugarcane showed a significant difference in the variable value of sucrose content but the two factors did not interact significantly (Table 1). Sugarcane genotypes with good ratooning ability will show a low yield decline until the second ratoon (Masri & Amein, 2015).

Ratooning ability (KK) can then be evaluated based on the sucrose content produced by the first crop of sugarcane, the first ratoon and the second ratoon. The sugarcane M3.2 genotype got the highest KK value of 80.69% but did not differ much from the M3.3 genotype (Table 4). The KK value of more than 75% obtained by all mutant sugarcane genotypes indicates the stable sucrose content of mutant sugarcane until the second ratoon. Selection of the best genotypes based on sucrose content will improve selection efficiency and increase heritability (Todd & Johnson, 2021).

Table 4. Ratooning effect on ratoon ability value of sucrose content (%) in all mutated sugarcane genotypes.

Genotype (G)	KK (%)
BL	69.70
M3.2	80.69
M3.3	83.37
M3.4	76.30

Note: BL = original Bululawang yield potential 10.81%; M3.2 = mutant yield potential 18.58%; M3.3 = mutant yield potential 16.58%; M3.4 = mutant yield potential 15.57%; KK = ratooning ability.

The high ratooning ability of each sugarcane genotype indicated its characteristics as a superior variety. Low ratooning ability in sugarcane plants will limit productivity and farmer profit (Songsri et al., 2019). The results in this experiment showed that the mutated Bululawang sugarcane in all observation variables had relatively the same statistical value in the first and second ratoon. The genetic potential of a variety to provide better yields in first plant and ratooning cultivation is a main point for maintaining high sugarcane productivity (Dumont et al., 2019).

CONCLUSIONS

The average stalk weight and percentage of sucrose content in all mutant genotypes were not significantly different, but significantly different from non-mutant sugarcane. The ratooning abilities of all mutant genotypes in the first and second ratoons were also not significantly different, but significantly different from those of the non-mutants. This means that all genotypes of mutant sugarcane have superior characteristics compared to non-mutant sugarcane.

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REFERENCES

Abu-Ellail, F. F. B., El-Azez, Y. M. A., & Bassiony, N. A. (2019). Assessment of ratooning ability and genetic variability of promising sugarcane varieties under middle Egypt conditions. *Electronic Journal of Plant Breeding*, *10*(1), 143–154.

Antika, L., & Ingesti, P. S. V. R. (2020). Analysis of the length of time of sugar cane (*Saccharum officinarum* L.) left in the field against the yield value. (In Indonesian.). *Jurnal Ilmu Pertanian Tropika Dan Subtropika*, *5*(1), 19–23.

Bezerra, J. D. C., Ferreira, G. D. G., Campos, J. M. de S., de Oliveira, M. W., de Andrade, A. P., & Junior, J. R. S. do N. (2017). Biometric and chemical characteristics of sugarcane varieties for use as forage in limiting soil water conditions. *Brazilian Journal of Animal Science*, *46*(5), 384–392.

Djumali, Heliyanto, B., & Khuluq, A. D. (2019). Evaluation of potential sugar cane clones in dry land. (In Indonesian.). *Jurnal Agronomi Indonesia*, *46*(3), 328–336.

Dumont, T., Thong-Chane, A., Barau, L., Siegmund, B., & Hoarau, J. Y. (2019). Genetic variabilities and genetic gains for yield components in regional sugarcane breeding programmes on Réunion Island. *Sugar Technology*, *21*(6), 868–878.

Junior, F. R., Junior, W. Q. R., Ramos, M. L. G., Da Silva Batista, F. P., De Lima, C. A., & Rocha, O. C. (2018). Biometric responses of third ratoon sugarcane varieties under variable water regime. *Comunicata Scientiae*, *9*(1), 81–92.

Kadarwati, F. T., Santoso, B., & Khuluq, A. D. (2015). Increased production and yield of ratoon sugarcane. (In Indonesian.). *Jurnal Litri*, *21*(4), 199–205.

Masri, M. I., & Amein, M. M. M. (2015). Yield potential and ratooning ability of some sugar cane genotypes. *Journal of Plant Breeding and Crop Science*, *7*(8), 262–274.

Mehareb, E. M., & Galal, M. O. A. (2018). Ratooning ability of some promising Egyptian sugarcane varieties. *Journal of Sugarcane Technology*, *30*(2), 50–59.

Nurhidayati, Basit, A., & Sunawan. (2013). First cane yield, ratoon and nutrient use efficiency due to substitution of ammonium sulfate plant and ratoon (In Indonesian.). *Jurnal Agronomi Indonesia*, *41*(1), 54–61.

Purnamaningsih, R., & Hutami, S. (2016). Increasing Al-tolerance of sugarcane using ethyl methane sulphonate and in vitro selection in the low pH media. *HAYATI Journal of Biosciences*, *23*(1), 1–6.

Riajaya, P. D., Kadarwati, F. T., & Djumali, . (2016). Potential of climate resources in bone regency for development of sugarcane, (In Indonesian.). *Buletin Tanaman Tembakau, Serat & Minyak Industri*, *7*(1), 28.

Setiawan, R. B., Khumaida, N., & Dinarti, D. (2015). Induction of wheat (T*riticum aestivum* L.) embryogenic callus mutations via gamma ray irradiation for high temperature tolerance. (In Indonesian.). *Jurnal Agronomi Indonesia*, *43*(1), 36–44.

Shikanda, E., Jamoza, J., & Kiplagat, O. (2017). Genotypic evaluation of sugarcane (*Saccharum* spp. Hybrids) clones for sucrose content in western Kenya. *Journal of Plant Breeding and Crop Science*, *9*(3), 30–36.

Songsri, P., Nata, J., Bootprom, N., & Jongrungkl, N. (2019). Performances of elite sugarcane genotypes for agro-physiological traits in relation to yield potential and ratooning ability under rain-fed conditions. *Journal of Agronomy*, *19*(1), 1–13.

Thirugnanasambandam, P. P., Hoang, N. V., Furtado, A., Botha, F. C., & Henry, R. J. (2017). Association of variation in the sugarcane transcriptome with sugar content. *BMC Genomics*, *18*(1), 1–22.

Todd, J., & Johnson, R. (2021). Prediction of ratoon sugarcane family yield and selection using remote imagery. *Agronomy*, *11*(7), 1–11.

Wei, Q., CaiWen, W., Jun, Z., PeiFang, Z., Kun, Y., XueKuan, C., Li, Y., & QianChun, Z. (2017). Research on ratoon ability of sugarcane: I. Relationship between ratooning ability and morphological characteristics of ratoon stools. *Journal of Agricultural Sciences*, *30*(5), 989–993.

Weksanthia, N., Chaisan, T., Wannarat, W., Chotchutima, S., & Jompuk, P. (2021). Mutagenesis and identification of sugarcane mutants using survival on polyethylene glycol and leaf damage under managed water stress. (In Indonesian.). *International Journal of Agronomy*, *1*(1), 1–9.

Windiyani, I. P., & Mahfut. (2021). Genetic diversity of sugarcane (*Saccharum officinarum* L.) based on morphological characters. *Tropical Genetics*, *1*(1), 6–11.

Xu, F., Wang, Z., Lu, G., Zeng, R., & Que, Y. (2021). Sugarcane ratooning ability: Research status, shortcomings, and prospects. *Biology*, *10*(10), 1–13.