UDC 633

THE GROWTH AND PRODUCTION OF POTENTIAL SUGARCANE CLONES IN ALFISOL SOIL

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ABSTRACT
A sufficient water supply has been a problem for sugarcane plantations on dry land. Therefore, efforts must be taken to solve the problem to achieve sugar self-sufficiency. Creating new varieties that are drought resistant is one way to solve the problem. This study was the manifestation of such an effort. The research was conducted in KP Ngemplak Pati from October 2018 to December 2019. The research material included clones from 2014-2016 crosses (89 clones). As a comparison, 8 parental and 2 drought-resistant varieties (BL and PS 881) were planted. Each clone and variety was planted in plots consisting of 3 rows. Each row was 10 meter-long. The center-to-center (CTC) distance was 110 cm, so the row factor (FJ) is 8100. Fertilization was done at a dose of 160 kg N + 70 kg P_2O_5 + 60 kg K_2O per ha or equivalent to 800 kg ZA + 200 kg SP36 + 100 kg of KCl per ha. This study aims to obtain new superior sugarcane clones of high production and drought resistance characteristics. Compared with their parents, the results of 89 crossed clones showed the following. (1) The sugar yield varied from 3.76 to 27.58 t/ha, with an average of 11.92 t/ha or an increase of 26.94%. (2) Sucrose content varied from 6.522 to 14.12%, with a mean of 10.67% or an increase of 5.42%. (3) The extracting factor varied from 0.456 to 0.669, with an average of 0.591 or a decrease of 4.52%. (4) The juice value varied from 12.12 to 23.21, with an average of 18.02% or an increase of 10.25%. (5) Productivity varied from 47.6 to 220.8 t/ha, with an average of 110.7 t/ha or an increase of 20.76%. (6) The number of stalks per meter of row varied from 5.6 to 20.7 stalks, with an average of 9.6 stalks or an increase of 15.05%. (7) Cane weight varied from 0.65 kg/stalk to 2.36 kg/stalk, with an average of 1.43 kg/stalk or an increase of 3.80%. (8) Stalk length varied from 140.0 cm to 283.0 cm, with an average of 212.7 cm or an increase of 13.65%. (9) Stalk diameter varied from 21.0 mm to 36.4 mm, with an average of 28.1 mm or an increase of 0.83%. (10) The relationship between cane weight and the photosynthetic rate resulted in a correlation coefficient of 0.884; this means that the photosynthetic rate determines 88.4% of the cane weight. (11) The photosynthetic rate under the light intensity of 100 mol/m^2/sec and a temperature of 35^{o}C varied from 9.14 to 15.63 molCO_2/m^2/sec, with an average of 10.85 molCO_2/m^2/sec or a decrease by 4.27%. (12) The maximum photosynthetic rate varied from 10.21 to 22.10 molCO_2/m^2/sec, with an average of 12.89 molCO_2/m^2/sec or a decrease of 8.10%. (13) The chlorophyll content varied from 9.9 to 38.02, with an average of 20.51 or an increase of 3.84%. Further studies are needed to obtain clones with high productivity and drought-resistant characteristics.

KEY WORDS
Growth, production, clone, sugarcane, potential, alfisol

Using superior varieties of high quality and productivity is one way to ensure the success of commodity development; this also applies to sugarcane. Sugarcane is mainly planted on dry land. Sugarcane covered 422,178 ha in Indonesia in 2019, an increase of 3.17% compared to 2018 (Dirjenbun 2020). Of the total sugarcane areas, more than 60% is dry land (Hadisaputro et al., 2008). One of the challenges in planting sugarcane on dry land is the limited water availability causing the plant to experience abiotic stress or drought stress. Drought stress significantly affects sugarcane growth (Murdiyatmoko & Nurmalasari, 2002). One way to solve the problem is using drought-resistant varieties.

Nevertheless, planting sugarcane on dry land is still possible using drought-resistant varieties. Therefore, we need more drought-resistant sugarcane varieties along with the increasing area of dry land for sugarcane planting. The existing sugarcane varieties result from single species selection, the result of evolution and hybridization of the *Saccharum* complex. This hybridization occurs both naturally and by human intervention. The high-yielding and drought-resistant sugarcane varieties can be obtained from the *Saccharum* complex because of the nature of its roots (Matsuoka & Garcia, 2011). There are several *Saccharum* complexes, such as Saccharum, Erianthus, Miscanthus, Sclerostachya, and Narenga (Besse et al., 1997). Hybridization or crossbreeding is a conventional way to obtain a new superior variety with high productivity and drought-resistant characteristics. The selection of female parents is crucial because the female parents pass down the high productivity characteristic, while the drought-resistant trait is inherited from the male parents. One sign of the high productivity of sugarcane can be seen from the size of the stalk. Sugarcane productivity, including cane weight and the number of stalks, is affected by plant genetics (Abdurrakhman et al., 2020).

MATERIALS AND METHODS OF RESEARCH

The study was conducted in KP Ngemplak Pati from October 2018 to December 2019. The research material included the clones of the 2014 to 2016 crosses (89 clones). We also used 8 parents and 2 drought-resistant varieties (BL and PS 881) as a comparison. The tools used include sugarcane crushing machines, hand refractometers, Saccharomats, Portable Photosynthesis, Chlorophyll Content Meters, meters, scales, calipers, hand refractometers, and other tools.

We planted 89 clones from the 2014 to 2016 crossbreeding (8 clones from the 2014 crossbreeding, 57 clones from the 2015 crossbreeding, and 24 clones from the 2016 crossbreeding) and 10 varieties as a comparison (Table 1). Each clone and variety was planted in a block of 3 rows, and each row was 10 meters long. The center-to-center (CTC) distance was 110 cm, and the row spacing factor (FJ) was 8100. We used a bud set that had been grown in a nursery. Seedlings of 1.5 months old were selected uniformly. The selected seeds were planted at a distance of 50 cm between plants, so we had 45 plants per plot. Organic material in the form of petrogenic fertilizer was applied before planting in each row at a dose of 1 ton per ha.

Fertilization was applied at a dose of 160 kg N + 70 kg P_2O_5 + 60 kg K_2O per ha or equivalent to 800 kg ZA + 200 kg SP36 + 100 kg KCl per ha. SP36 fertilizer was applied during tillage. ZA fertilizer was applied 2 times: 2 weeks after planting as much as 300 kg and 2 months after the first application of as much as 500 kg. All doses of KCl fertilizer were applied at the same time as the second ZA fertilization. Other plant maintenance included weeding, while pest and disease control was done following the conditions in the field.

Growth observations were carried out before harvest by measuring the number of stalks per row, stalk length, and stalk diameter. The stalks counted were those with a length of > 150 cm and a diameter of at least 20 mm. In addition, observations of photosynthetic rate, chlorophyll content, and the maximum photosynthetic rate was carried out during the stalk formation phase (age 5 months). The photosynthetic rate was observed using a Portable Photosynthesis tool, and the chlorophyll content was observed using a Chlorophyll Content Meter.

The harvested cane weight, cane weight, juice weight, and Brix and pol values were observed at harvest time. The harvested cane weight (Bbatnen) was measured by weighing all the stalks. Sugarcane productivity (Protas) is calculated by the formula:

$$\text{Protas} = \frac{FJ\ x\ Bbatnen}{3\ x\ 10\ x\ 1000} = \ldots \text{ t/ha}$$

Where: Protas = sugarcane productivity; Bbatnen = the harvested cane weight; FJ = row spacing factor.

Cane weight (Bbat) was measured by weighing 6 samples of harvested stalks. Next, juice weight (BNir) was measured by weighing the juice of the 6 samples of harvested stalks. Finally, the extracting factor (FP) was calculated using the formula:

$$FP = \frac{BNir}{Bbat}$$

Where: FP = extracting factor; BNir = juice weight; BBat = cane weight.

The Brix value was obtained using a hand refractometer. The pol value was measured using a Saccharomat. Finally, the Brix and pol values were used to measure the juice value. Thus, the juice value (NN), sucrose content (Rend), and sugar yield (Hab) can be calculated using the formula:

$$NN = Pol – \{0.4 \times (Brix – Pol)\}$$
$$Rend = FP \times NN\ (\%)$$
$$Hab = Protas \times Rend\ (t/ha)$$

Table 1 – List of Clones and Varieties Tested

No.	Clones and Varieties	No.	Clones and Varieties	No.	Clones and Varieties
1	MLG 14/2/76	34	MLG 15/11/16	67	MLG 16/2/11
2	MLG 14/2/49	35	MLG 15/11/26	68	MLG 16/2/8
3	MLG 14/2/17	36	MLG 15/11/24	69	MLG 16/2/10
4	MLG 14/5/18	37	MLG 15/13/13	70	MLG 16/2/5
5	MLG 14/66	38	MLG 15/15/15	71	MLG 16/2/1
6	MLG 14/212	39	MLG 15/13/18	72	MLG 16/2/4
7	MLG 14/352	40	MLG 15/17/2	73	MLG 16/2/8
8	MLG 14/354	41	MLG 15/17/1	74	MLG 16/2/7
9	MLG 15/1/37	42	MLG 15/25/15	75	MLG 16/2/10
10	MLG 15/1/6	43	MLG 15/25/2	76	MLG 16/2/12
11	MLG 15/1/39	44	MLG 15/25/24	77	MLG 16/2/3
12	MLG 15/2/8	45	MLG 15/28/16	78	MLG 16/2/2
13	MLG 15/2/144	46	MLG 15/28/6	79	MLG 16/3/1
14	MLG 15/2/127	47	MLG 15/28/11	80	MLG 16/3/2
15	MLG 15/2/150	48	MLG 15/28/18	81	MLG 16/3/4
16	MLG 15/2/78	49	MLG 15/37/7	82	MLG 16/3/3
17	MLG 15/2/125	50	MLG 15/34/8	83	MLG 16/3/5
18	MLG 15/116	51	MLG 15/34/1	84	MLG 16/4/1
19	MLG 15/2/57	52	MLG 15/35/11	85	MLG 16/4/2
20	MLG 15/2/152	53	MLG 15/33/10	86	MLG 16/5/1
21	MLG 15/2/47	54	MLG 15/33/54	87	MLG 16/6/1
22	MLG 15/2/159	55	MLG 15/33/12	88	MLG 16/6/2
23	MLG 15/2/156	56	MLG 15/40/1	89	MLG 16/6/3
24	MLG 15/2/46	57	MLG 15/43/10	90	PSDK 067
25	MLG 15/2/158	58	MLG 15/47/60	91	PS 864
26	MLG 15/2/171	59	MLG 15/47/50	92	PA 028
27	MLG 15/2/98	60	MLG 15/23/23	93	PS 881
28	MLG 15/2/124	61	MLG 15/47/49	94	TLH 2
29	MLG 15/10/9	62	MLG 15/47/52	95	BL
30	MLG 15/5/3	63	MLG 15/48/12	96	PA 0218
31	MLG 15/5/29	64	MLG 15/48/7	97	CENING
32	MLG 15/4/2	65	MLG 15/48/23	98	PS 862
33	MLG 15/5/4	66	MLG 16/1/1	99	PS 865

The data obtained were analyzed descriptively in the form of graphs. In addition, multiple linear regression analysis (Stepwise analysis) was conducted to determine the \ effect of the two variables on the primary variable.

RESULTS AND DISCUSSION

The clones of the 2014, 2015, and 2016 crossbreeding resulted in varied sugar yields of 3.76 to 27.58 t/ha, with an average of 11.92 t/ha or an increase of 26.94% from their parents and comparisons (Figure 1). All clones from the crossbreeding experienced a different increase in sugar yield. For example, the clones of the 2014 crossbreeding resulted in sugar yields of 6.26 to 13.61 t/ha, with an average of 9.64 t/ha or an increase of 2.68%. The parent and comparison variety resulted in the highest sugar yield was PS 865 of 12.53 t/ha (Figure 1a). Three of the 2014 crossbreeding clones resulted in higher sugar yields than PS 865 were 14/2/49, 14/2/76, and 14/5/18 (Figure 1b). The 2015 crossbreeding clones resulted in various sugar yields of 63.76 to 27.58 t/ha, with an average of 12.73 t/ha or an increase of 35.62%. As many as 29 clones from the 2015 crossbreeding resulted in higher sugar yields than PS 865 (Figure 1c). The 2016 crossbreeding clones resulted in various sugar yields of 4.36 to 19.76 t/ha, with an average of 10.74 t/ha or an increase of 14.40%. Seven clones of the 2016 crossbreeding resulted in higher sugar yields than PS 865, including 16/2/3, 16/2/5, 16/2/6, 16/2/10, 16/3/1, 16/3/2, and 16/3/3 (Figure 1d). Similar findings come from Soomro et al. (2012), stating that different sugarcane clones result in different yields.

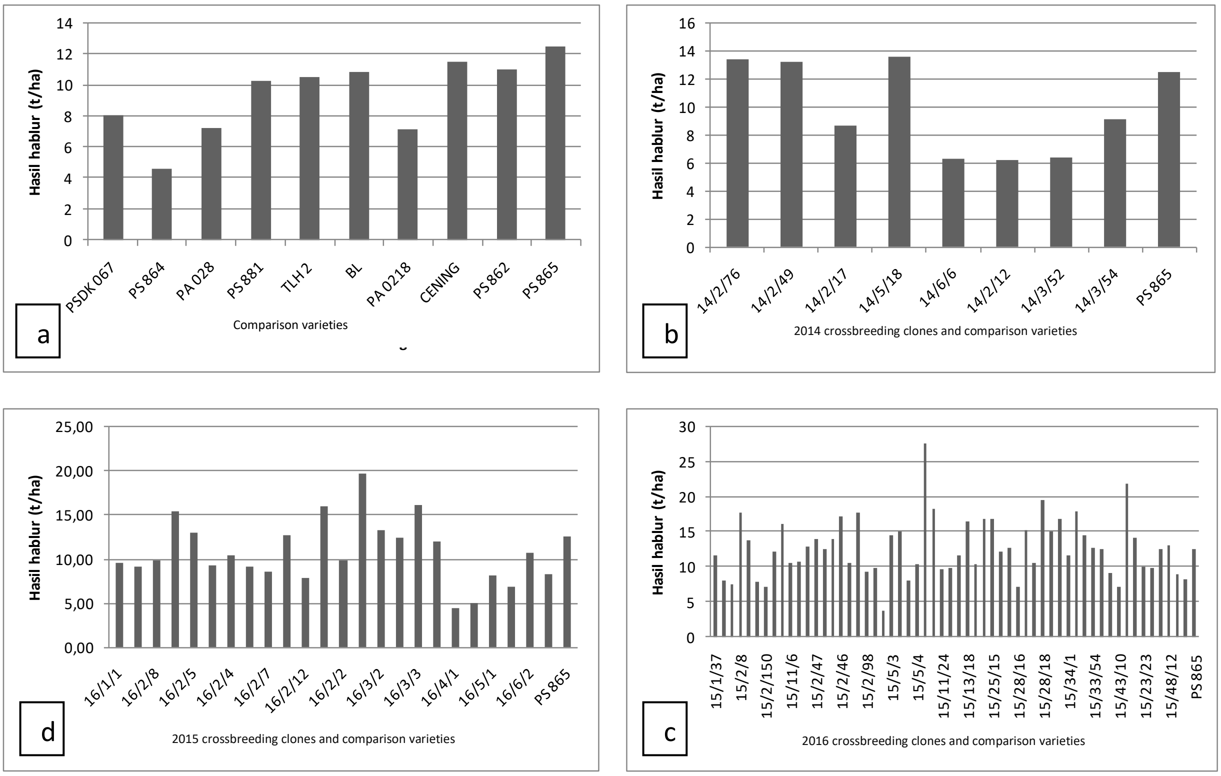

Figure 1 – Yields of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

The sugar yield reflects the sucrose content per unit area of land yield (Gomathi et al., 2013). Therefore, two main components comprise sugar yield: sucrose content and productivity (Dashora, 2012; Junejo et al., 2010). In this study, the relationship between sugar yield and sucrose content (Rend) and sugarcane productivity (Protas) was obtained by forming the equation: Sugar yield (Hab) = 0.54045 Rend + 0.87553 Protas - 0.41471 with a correlation coefficient (r) of 0.993. These results mean that 99.3% of the sugar yield is determined by sucrose content (42.96%) and sugarcane productivity (56.34%), respectively. Thus, the increase in sugar yields in the clones of the 2014, 2015, and 2016 crossbreeding occurred through increased sugarcane productivity and sucrose content.

The sucrose content of the 2014, 2015, and 2016 crossbreeding clones varied from 6.522 to 14.12%, with an average of 10.67% or an increase of 5.42% from the parents and comparison (Figure 2). However, not all clones showed an increased sucrose content. For example, the 2014 crossbreeding clones produced varied sucrose content from 8.06% to 14.12%, with an average of 11.89% or an increase of 17.50%. The parent and comparison variety producing the highest sucrose content was PS 865 with 13.01% (Figure 2a). Two

2014 crossbreeding clones resulted in higher sugar yields than PS 865 were 14/2/49 and 14/5/18 (Figure 2b). The 2015 crossbreeding clones produced varied sucrose content from 6.52% to 13.65%, with an average of 10.89% or an increase of 7.63%. Five of the 2015 crossbreeding clones resulting in higher sucrose content than PS 865 were 15/2/125, 15/2/171, 15/5/3, 15/11/26, and 15/13/13 (Figure 2c). The 2016 crossbreeding clones resulted in various sucrose content from 7.07% to 13.94%, with an average of 9.73% or a decrease of 3.87%. However, two clones of the 2016 crossbreeding resulted in higher sucrose content than PS 865, including 16/3/1 and 16/3/3 (Figure 2d). Similar findings come from Schultz et al. (2017), stating that different sugarcane clones result in different sucrose content.

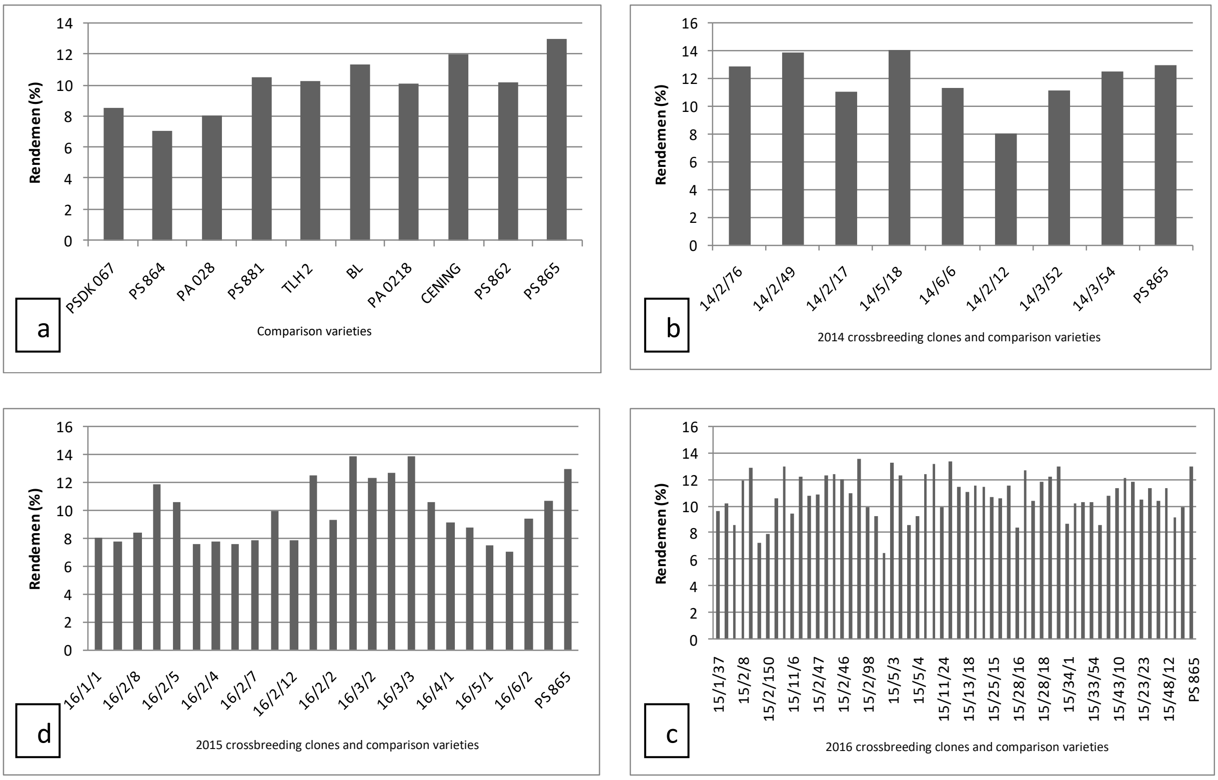

Figure 2 – Sucrose content of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

Sucrose content reflects the quality of sucrose in harvested cane stalks; the higher the sucrose content, the more sucrose the stalks contain (Inoue et al., 2009). Thus, the sucrose content is determined by the juice quality (reflected through the extracting factor or FP) and the sucrose content in the juice (reflected through the juice value or NN). The relationship of the three components in this study is presented as follows Rend = 0.84946 FP + 0.97066 NN – 0.73638 with a correlation coefficient (r) of 0.998. This means that 99.8% of the sucrose content is determined by the extracting factor (36.41%) and the juice value (63.39%), respectively. The influence of the juice value was higher than the extracting factor means that an increase in sucrose content in the 2014, 2015, and 2016 crossbreeding clones occurred through an increased juice value.

The extracting factor of the 2014, 2015, and 2016 crossbreeding clones varied from 0.456 to 0.669, with an average of 0.591 or a decrease of 4.52% from the parents and comparison (Figure 3). However, the decrease in the extracting factor was different for each clone. For example, the 2014 crossbreeding clones produced varied extracting factors from 0.573 to 0.650, with an average of 0.605 or a decrease of 2.21%. The parent and comparison variety producing the highest sucrose content was BL with 0.680 (Figure 3a). The 2015 crossbreeding clones produced varied extracting factors from 0.450 to 0.662, with an average of 0.594 or a decrease of 4.10%—none of the 2015 crossbreeding clones resulted in a higher extracting factor than BL (Figure 3c). The 2016 crossbreeding clones resulted in various extracting factors from 0.510 to 0.667, with an average of 0.580 or a decrease of 6.30%—none of the 2016 crossbreeding clones resulted in a higher extracting factor than BL (Figure 3d). Similar findings come from Supriyadi et al. (2018), stating that different sugarcane clones result in different extracting factors.

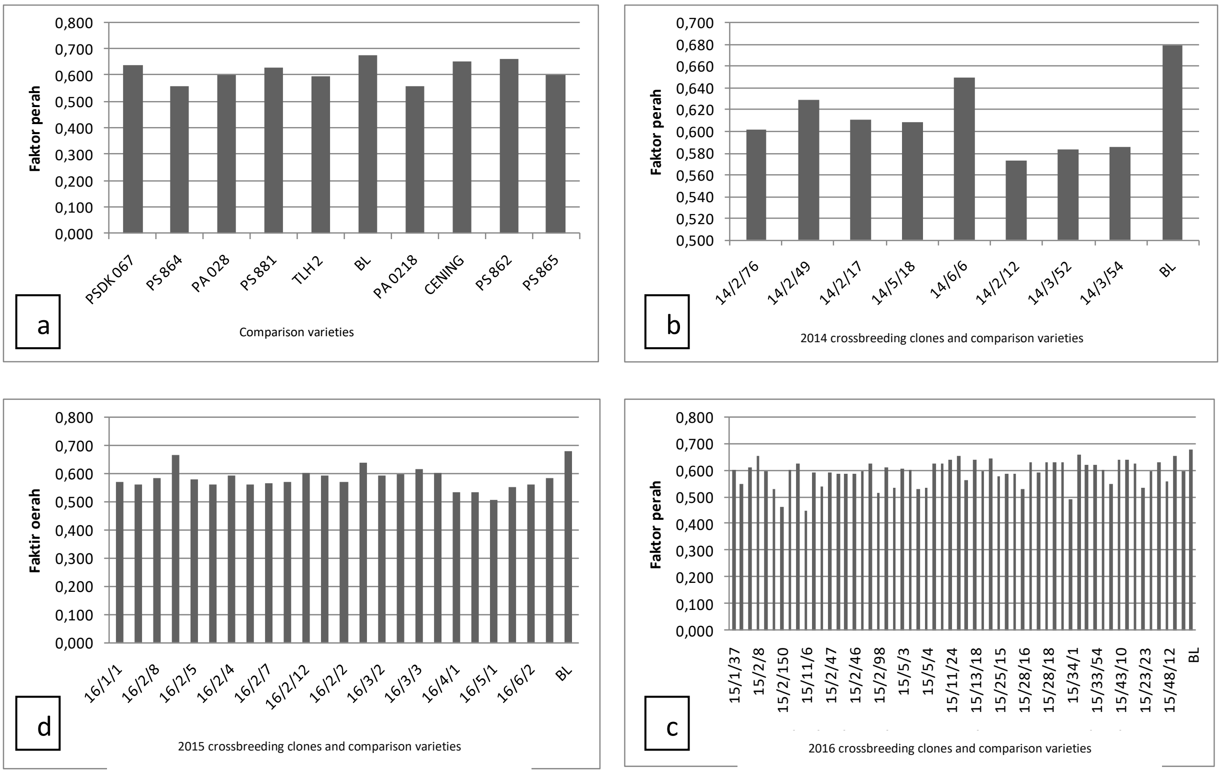

Figure 3 – The extracting factor of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

The juice value of the 2014, 2015, and 2016 crossbreeding clones varied from 12.12 to 23.21, with an average of 18.02% or an increase of 10.25% from the parents and comparison (Figure 4). However, not all clones resulted in the same increase in the juice value. For example, the 2014 crossbreeding clones produced a juice value from 14.06 to 23.21, with an average of 19.62 or an increase of 20.09%. The parent and comparison variety producing the highest juice value was PS 865 with 21.52 (Figure 4a). Two 2014 crossbreeding clones resulted in higher juice values than PS 865 were 14/2/49 and 14/5/18 (Figure 4b). The 2015 crossbreeding clones produced varied juice values from 12.12 to 21.76, with an average of 18.35 or an increase of 12.28%. Three of the 2015 crossbreeding clones resulting in higher juice values than PS 865 were 15/2/144, 15/2/171, and 15/5/3 (Figure 4c). The 2016 crossbreeding clones resulted in juice values from 12.84 to 22.60, with an average of 16.69 or an increase of 2.15%. Two clones of the 2016 crossbreeding resulted in higher juice values than PS 865, including 16/3/1 and 16/3/3 (Figure 4d). Under the same environmental conditions, the juice value is affected by plant genetics (Chohan et al., 2014). Different sugarcane clones result in different juice values (Djumali et al., 2018).

The productivity of the 2014, 2015, and 2016 crossbreeding clones varied from 47.6 t/ha to 220.8 t/ha, with an average of 110 t/ha or an increase of 20.76% from the parents and comparison (Figure 5). However, not all clones experienced increased productivity. For example, the 2014 crossbreeding clones produced varied productivity values from 55.5 t/ha to 104.2 t/ha, with an average of 79.7 t/ha or a decrease of 13.05%.

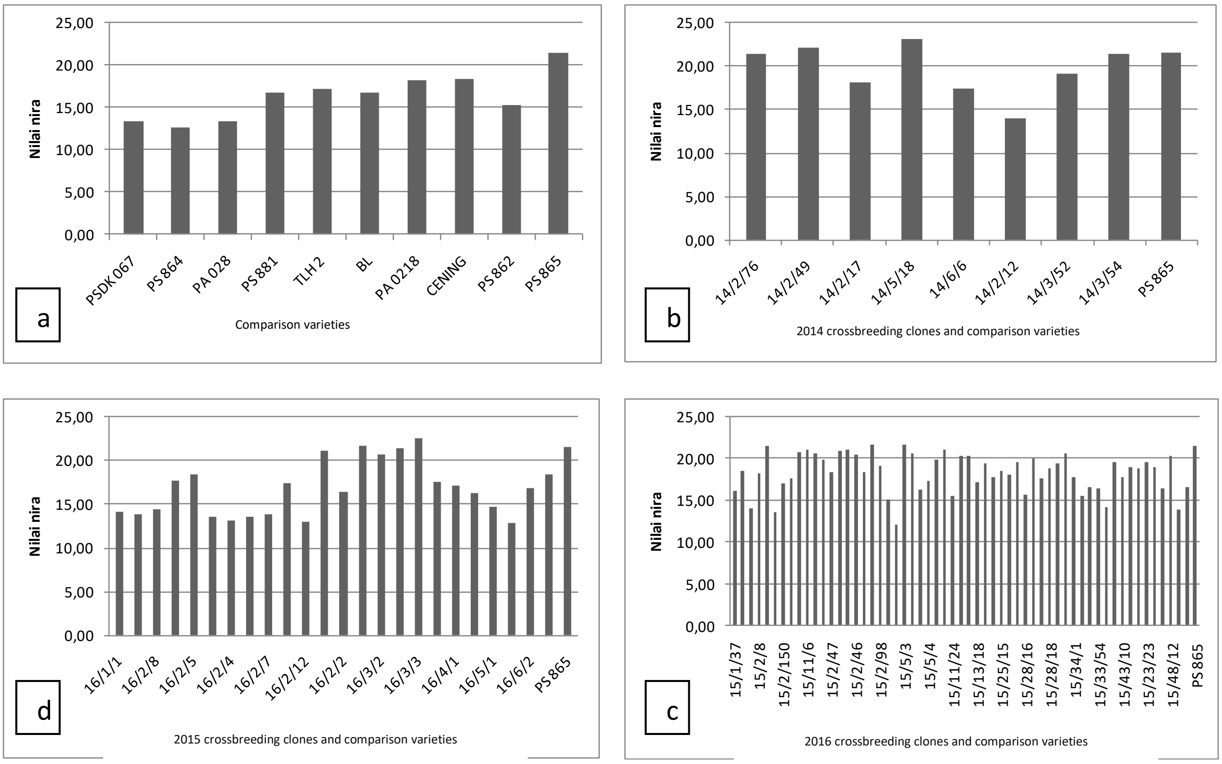

Figure 4 – The juice value of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

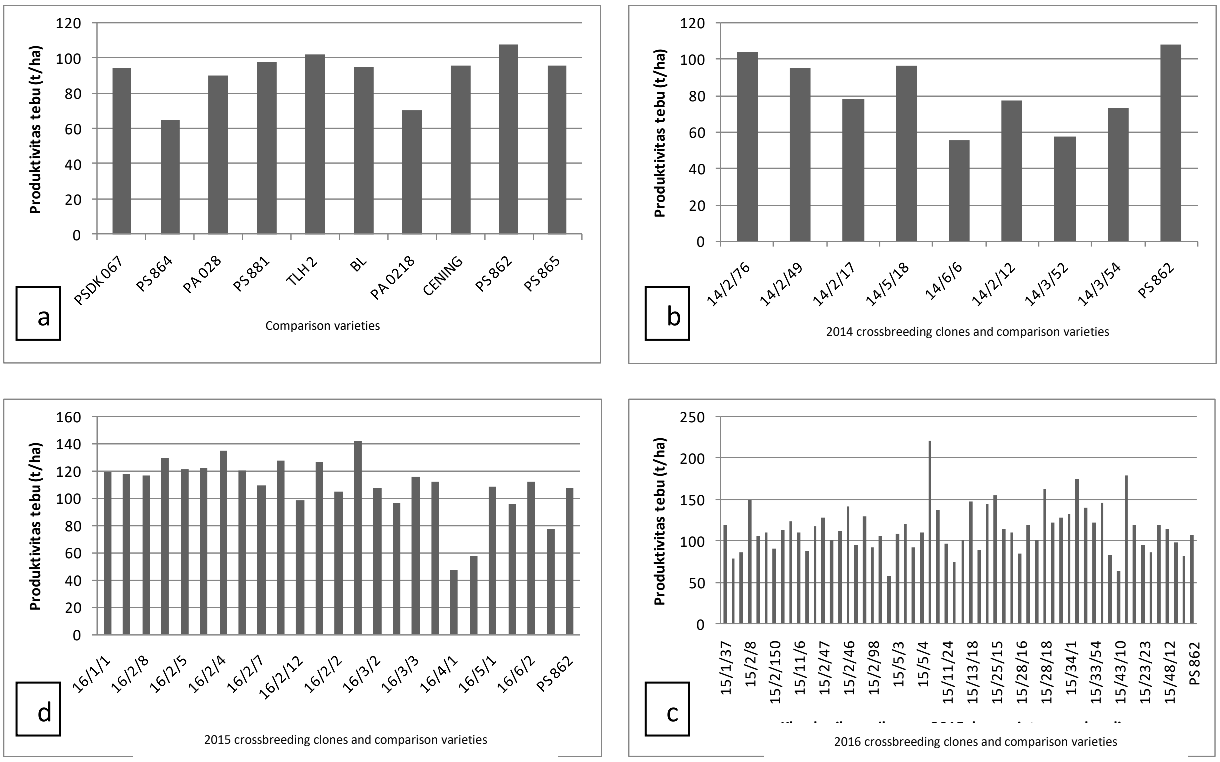

Figure 5 – Sugarcane productivity of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

The parent and comparison variety producing the highest productivity was PS 862 with 108.2 t/ha (Figure 5a). None of the 2014 crossbreeding clones resulted in higher productivity than PS 862 (Figure 5b). The 2015 crossbreeding clones produced varied productivity values from 57.8 t/ha to 220.8 t/ha, with an average of 115.6 t/ha or an increase of 26.04%. As many as 34 of the 2015 crossbreeding clones showed higher productivity than PS 862 (Figure 5c). The 2016 crossbreeding clones resulted in varied productivity values from 47.6 t/ha to 142.3 t/ha, with an average of 109.5 t/ha or an increase of 19.48%. As many as 16 of the 2016 crossbreeding clones resulted in higher productivity than PS 862, while 8 clones showed lower productivity than PS 862 (Figure 5d). Different sugarcane clones result in different productivity (Kumar et al., 2012; Gulati et al., 2015).

Sugarcane productivity (Protas) illustrates the weight of harvested cane stalks per unit of land area (Khalid et al., 2015). Stalk weight (Bbat) and the number of stalks (Jbat) are components of sugarcane productivity (Patel et al., 2014). Thus, the following equation was obtained to calculate productivity in this study Protas = 0.83763 Bbat + 0.88757 Jbat - 0.42221, with a correlation coefficient (r) of 0.969. This equation means that 96.9% of sugarcane productivity was influenced by cane weight (60.15%) and the number of stalks (36.75%). The cane weight showed a higher influence on productivity than the number of stalks, which means that increased sugarcane productivity of the 2014, 2015, and 2016 crossbreeding clones occurred through increased cane weight.

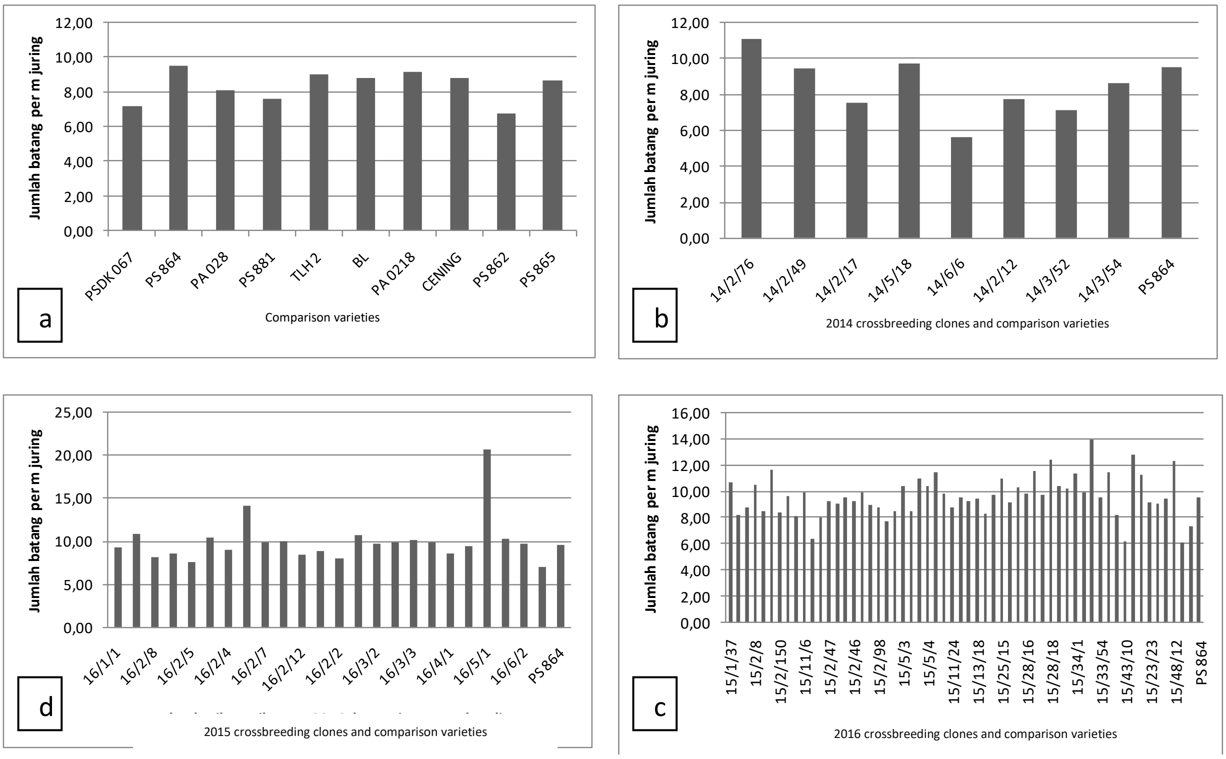

Figure 6 – The number of stalks per meter of the row of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

The number of stalks per meter of the row of the 2014, 2015, and 2016 crossbreeding clones varied from 5.6 stalks to 6.7 stalks, with an average of 9.6 stalks or an increase of 15.05% from the parents and comparison (Figure 6). All clones experienced an increased number of stalks, although the values were different. For example, the 2014 crossbreeding clones produced a varied number of stalks, from 5.6 stalks to 11.1 stalks, with an average of 8.4 stalks or an increase of 0.01%. The parent and comparison variety producing the highest number of stalks was PS 864, with 9.5 stalks (Figure 6a). Two of the 2014 crossbreeding clones resulted in a higher number of stalks than PS 864, which were 14/2/76 and14/15/18 (Figure 6b). The 2015 crossbreeding clones produced a varied number of stalks, from 6.2 stalks to 13.9 stalks, with an average of 9.7 stalks or an increase of 15.51%. As many as 27 of the 2015 crossbreeding clones had a higher number of stalks than PS 864 (Figure 6c).

The 2016 crossbreeding clones resulted in a varied number of stalks, from 7.0 stalks to 20.7 stalks, with an average of 10 stalks or an increase of 18.95%. As many as 13 of the 2016 crossbreeding clones resulted in a higher number of stalks than PS 864, including 16/2/1, 16/2/7, 16/2/8, 16/2/10, 16/2/11, 16/3/1, 16/3/2, 16/3/3, 16/3/4, 16/3/5, 16/5/1, 16/6/1, and 16/6/2 (Figure 6d). Different sugarcane clones result in different numbers of stalks (Getaneh et al., 2015; Santoso et al., 2015).

The cane weight of the 2014, 2015, and 2016 crossbreeding clones varied from 0.65 kg/stalk to 2.36 kg/stalk, with an average of 1.43 kg/stalk or an increase of 3.80% from the parents and comparison (Figure 7). Not all clones experienced increased cane weight. For example, the 2014 crossbreeding clones produced varied cane weights, from 1.00 kg/stalk to 1.27 kg/stalk, with an average of 1.17 kg/stalk, or a decrease of 14.89%. The parent and comparison variety producing the highest cane weight was PS 862, with 1.96 kg/stalk (Figure 7a). None of the 2014 crossbreeding clones resulted in higher cane weights than PS 862 (Figure 7b). The 2015 crossbreeding clones produced varied cane weights, from 0.83 kg/stalk to 2.36 kg/stalk, with an average of 1.48 kg/stalk stalks or an increase of 7.15%. Three of the 2015 crossbreeding clones had heavier cane weights than PS 862, including 15/11/16, 15/35/11, and 15/48/7 (Figure 7c). The 2016 crossbreeding clones resulted in varied cane weights, from 0.65 kg/stalk to 1.98 kg/stalk, with an average of 1.41 kg/stalk or an increase of 2.80%. Only 1 clone of the 2016 crossbreeding had a heavier cane weight than PS 862 (Figure 7d). Different sugarcane clones planted in salt soil result in different cane weights (Simoes et al., 2016).

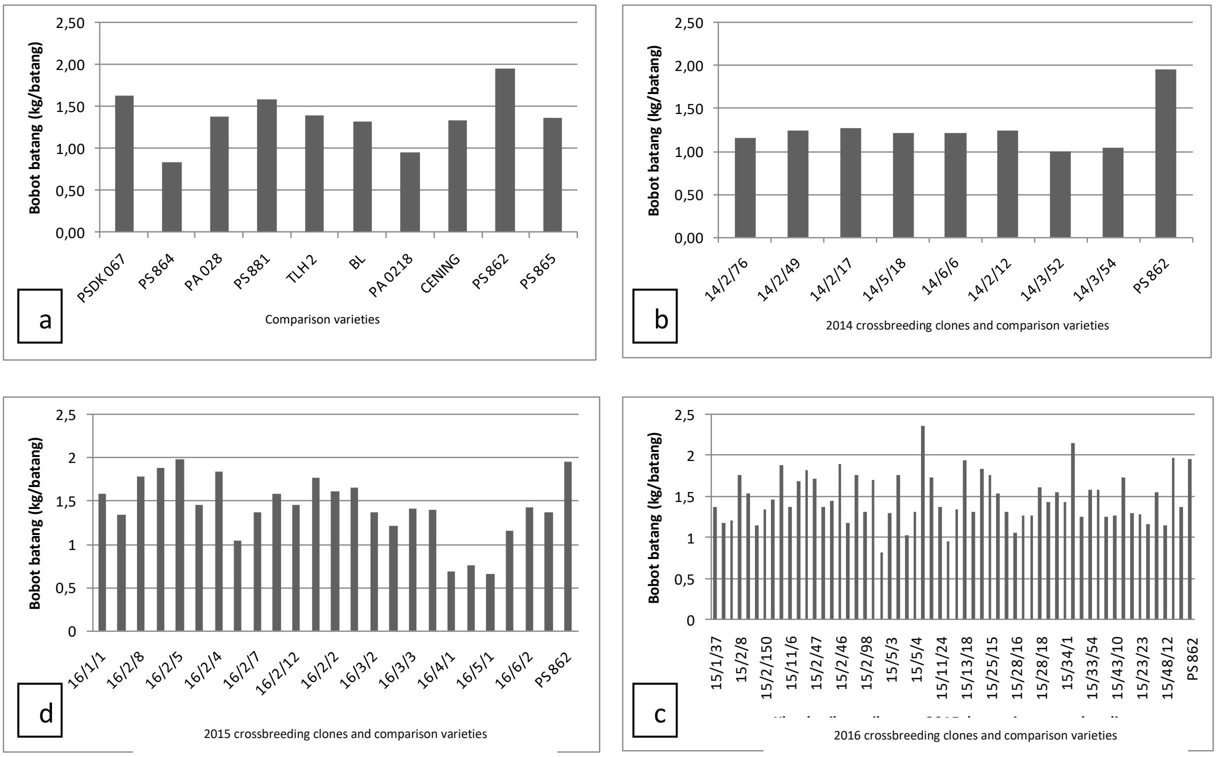

Figure 7 – Cane weight of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

According to Sajjad et al. (2014), stalk length (Pbat) and diameter (Dbat) are growth components that determine cane weight (Bbat). Thus, the following equation was obtained to calculate cane weight in this study Bbat = 0.47534 Pbat + 0.89814 Dbat - 0.44349 with a correlation coefficient (r) of 0.667. The results of these equations mean that 66.7% of the cane weight was determined by stalk length (31.02%) and diameter (35.68%). Djumali et al. (2016) also show that stalk length and diameter affect cane weight. However, the effect of the two components was not much different, meaning that increased cane weight of the

2014, 2015, and 2016 crossbreeding clones occurred through increased stem length and diameter.

The stalk length of the 2014, 2015, and 2016 crossbreeding clones varied from 140.0 cm to 283.0 cm, with an average of 212.7 cm or an increase of 13.65% from the parents and comparison (Figure 8). Not all clones experienced increased stalk length. For example, the 2014 crossbreeding clones produced varied stalk lengths, from 140.0 cm to 214.0 cm, with an average of 174.5 cm, or a decrease of 6.73%. The parent and comparison variety producing the highest stalk length was PSDK 064, with 242.0 cm (Figure 8a). None of the 2014 crossbreeding clones resulted in higher stalk lengths than PSDK 064 (Figure 8b). The 2015 crossbreeding clones produced varied stalk lengths, from 158.0 cm to 283.0 cm, with an average of 216.0 cm or an increase of 15.46%. As many as 15 of the 2015 crossbreeding clones had longer stalks than PSDK 064, including 15/2/8, 15/2/46, 15/2/47, 15/2/78, 15/2/125/ 15/2/127, 15/2/144, 15/2/152, 15/2/156, 15/5/3, 15/17/1, 15/25/15, 15/33/12, 15/33/12, and 15/47/60 (Figure 8c). The 2016 crossbreeding clones resulted in varied stalk lengths, from 155.0 cm to 262.0 cm, with an average of 217.5 cm or an increase of 16.27%. Seven of the 2016 crossbreeding clones had longer stalks than PSDK 064, including 16/2/2, 16/2/3, 16/2/4, 16/2/5, 16/2/7, 16/2/8, and 16/2/10 (Figure 8d). Different sugarcane clones result in different stalk lengths (Rahmad, 2016).

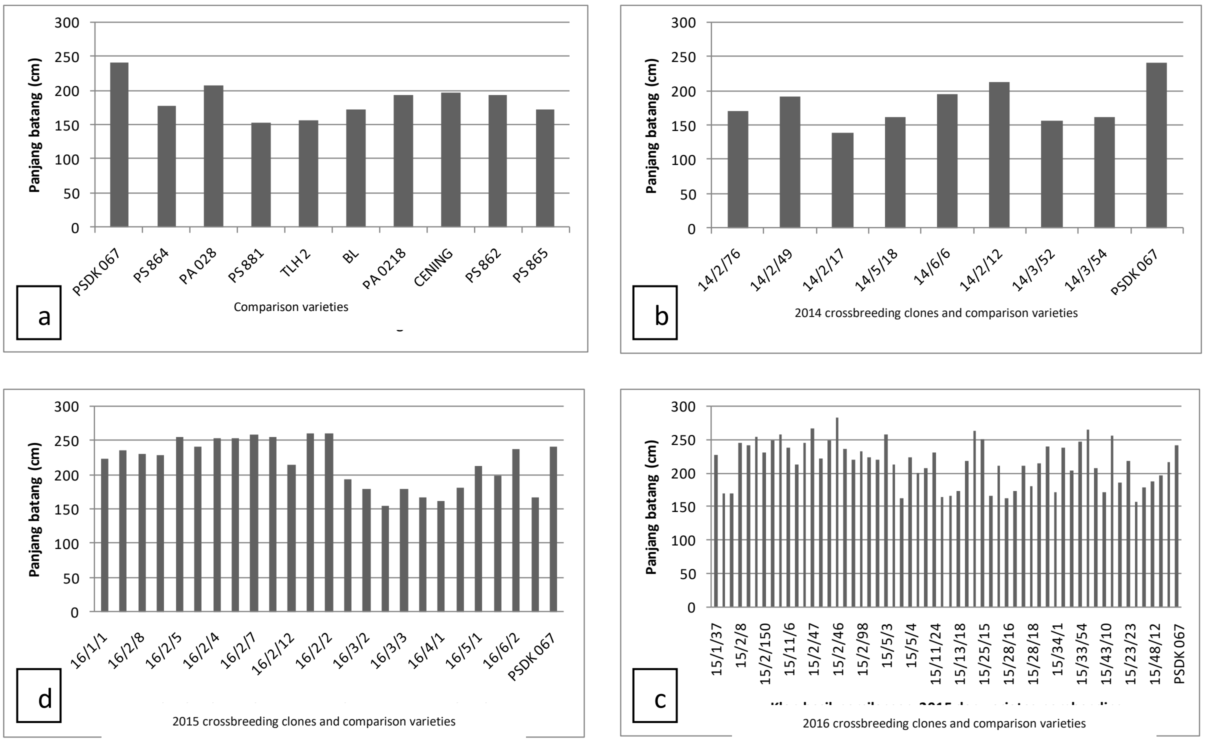

Figure 8 – Stalk length of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

The stalk diameter of the 2014, 2015, and 2016 crossbreeding clones varied from 21.0 mm to 36.4 mm, with an average of 28.1 mm or a decrease of 0.83% from the parents and comparison (Figure 9). Not all clones experienced decreased stalk diameters. For example, the 2014 crossbreeding clones produced varied stalk diameters, from 24.4 mm to 36.4 mm, with an average of 29.5 mm, or an increase of 4.14%. The parent and comparison variety producing the biggest stalk diameter was PS 862, with 233.88 mm (Figure 9a). One 2014 crossbreeding clone resulted in a bigger stalk diameter than PS 862, which was 14/5/8 (Figure 9b). The 2015 crossbreeding clones produced varied stalk diameters, from 22.7 mm to 36.2 mm, with an average of 28.0 mm or a decrease of 1.21%. One 2015 crossbreeding clone had a bigger diameter than PS 862, which was 15/48/7 (Figure 9c). The 2016 crossbreeding clones resulted in varied stalk diameters, from 21.0 mm to 32.7 mm, with an average of 27.9 mm or a decrease of 1.57%. None of the 2016 crossbreeding clones had bigger stalk diameters than PS 862 (Figure 9d). Different sugarcane clones result in different stalk diameters (Irsyad et al., 2016).

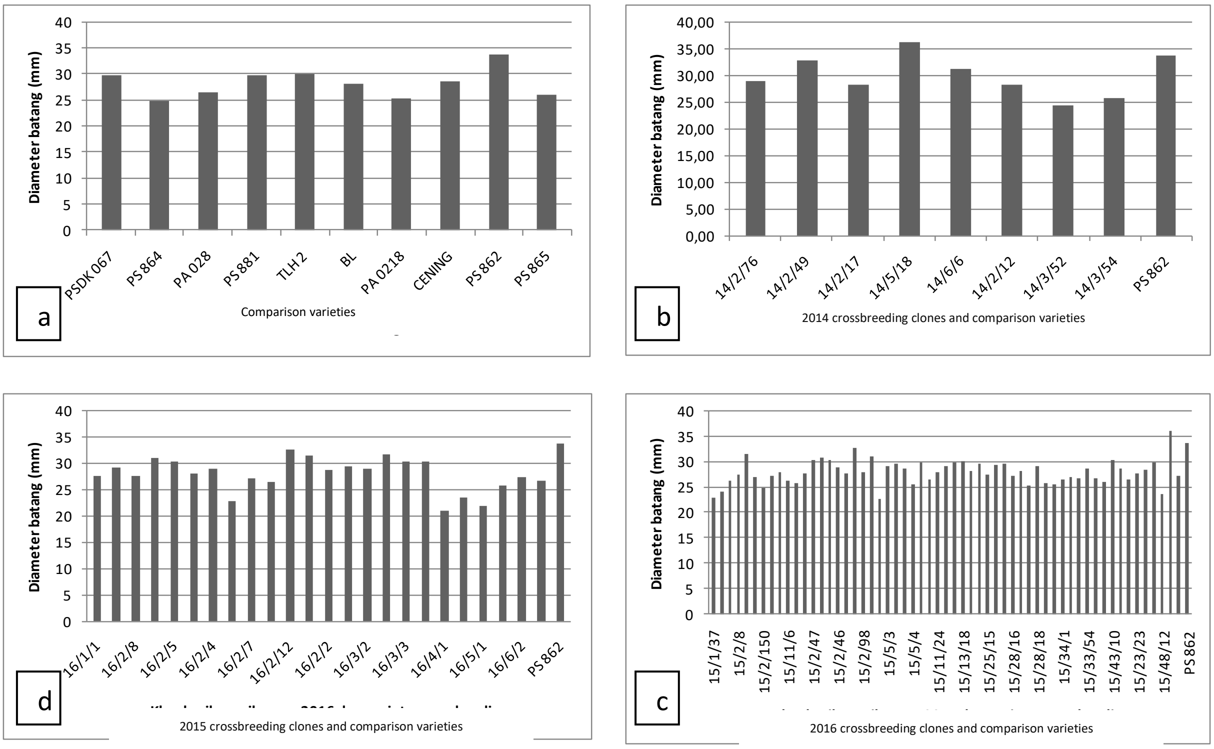

Figure 9 – Stalk diameter of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

Cane weight results from accumulated carbohydrates available for stalk growth during early growth until harvest (Streck et al., 2010); the more carbohydrates accumulated during this period, the greater the stem weight obtained (Silva et al., 2013). Within the same accumulation period, the accumulated carbohydrates available for growth are determined by the quantity of carbohydrates available for daily growth (Jones et al., 2011; Marin et al., 2011). Carbohydrates available for daily growth result from the photosynthetic process after being reduced by the daily need for the respiration process (Streck et al., 2010). In this study, the relationship between cane weight and the photosynthetic rate was obtained with a correlation coefficient of 0.884; these results mean that the photosynthetic rate determined 88.4% of cane weight in this study. Therefore, the value indicates that increased cane weight of the 2014, 2015, and 2016 crossbreeding clones occurred through increased photosynthetic rates.

The photosynthetic rate of the 2014, 2015, and 2016 crossbreeding clones under the light intensity of 1000 mol/m^2/sec and the temperature of 35^{o}C varied from 9.14 mol CO_2/m^2/sec to 15.63 mol CO_2/m^2/sec, with an average of 10.85 mol CO_2/m^2/sec or a decrease of 4.27% from the parents and comparison (Figure 10). Almost all clones experienced decreased photosynthetic rates. For example, the 2014 crossbreeding clones produced varied photosynthetic rates, from 9.14 mol CO_2/m^2/sec to 10.76 mol CO_2/m^2/sec, with an average of 9.84 mol CO_2/m^2/sec or a decrease of 13.14%. The parent and comparison variety producing the highest photosynthetic rate was PS 862, with 14.91 mol CO_2/m^2/sec (Figure 10a). None of the 2014 crossbreeding clones resulted in a higher photosynthetic rate than PS 862 (Figure 10b). The 2015 crossbreeding clones produced varied photosynthetic rates, from 9.33 mol CO_2/m^2/sec to 15.63 mol CO_2/m^2/sec, with an average of 10.87 mol CO_2/m^2/sec or a decrease of 4.07%. However, two 2015 crossbreeding clones had higher photosynthetic rates than PS 862, which were 15/11/16 and 5/35/11 (Figure 10c). The 2016 crossbreeding clones resulted in varied photosynthetic rates, from 9.68 mol $CO_2/m^2/sec$ to 15.22 mol $CO_2/m^2/sec$, with an average of 11.13 mol $CO_2/m^2/sec$ or a decrease of 1.80%. One 2016 crossbreeding clone had a higher photosynthetic rate than PS 862 (Figure 10d), which was 16/2/5. Different sugarcane phenotypes result in different photosynthetic rates (Silva et al., 2013).

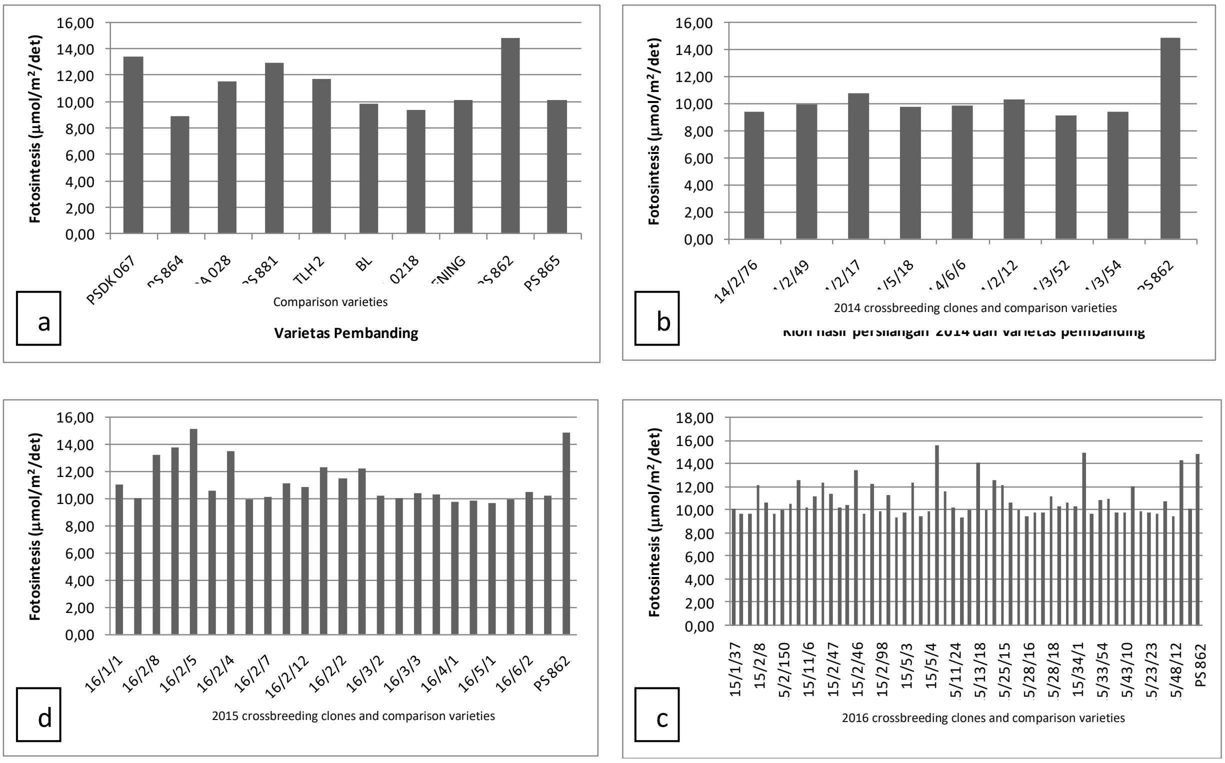

Figure 10 – Photosynthetic rates of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

Under no difference in the light intensity received by the leaves, the photosynthetic rate (Fot) is determined by the light efficiency to reduce CO_2 (EF0) and the maximum photosynthetic rate (Fotmak) (Penning deVries et al., 1989). Thus, the following equation was obtained to calculate the photosynthetic rate in this study Fot = 0.24668 EF0 + 0.68141 Fotmak + 0.08088 with a correlation coefficient (r) of 0.989. This means that 98.9% of the photosynthetic rate in this study was influenced by EF0 (0.91%) and Fotmak (97.99%). Therefore, the value indicates that the increased photosynthetic rate of the 2014, 2015, and 2016 crossbreeding clones occurred through an increased maximum photosynthetic rate.

The 2014, 2015, and 2016 crossbreeding clones produced varied values of the light efficiency to reduce CO_2, from 0.304 mol $CO_2/m^2/sec$ to 0.429 mol $CO_2/m^2/sec$, with an average of 0.371 mol $CO_2/m^2/sec$ or an increase of 3.21% from the parents and comparison (Figure 11). However, not all clones experienced increased light efficiency. For example, the 2014 crossbreeding clones produced varied light efficiency, from 0.304 mol $CO_2/m^2/sec$ to 0.397 mol $CO_2/m^2/sec$, with an average of 0.35 mol $CO_2/m^2/sec$ or a decrease of 2.5% from the parent and comparison varieties. The 2015 crossbreeding clones produced varied light efficiency, from 0.318 mol $CO_2/m^2/sec$ to 0.429 mol $CO_2/m^2/sec$, with an average of 0.377 mol $CO_2/m^2/sec$ or an increase of 5.02% from the parent and comparison varieties. The 2016 crossbreeding clones resulted in varied light efficiency, from 0.308 mol $CO_2/m^2/sec$ to 0.416 mol $CO_2/m^2/sec$, with an average of 0.362 mol $CO_2/m^2/sec$ or an increase of 0.82% from the parent and comparison varieties. Different tobacco of Temanggung cultivars produces different EF0 values (Djumali, 2010).

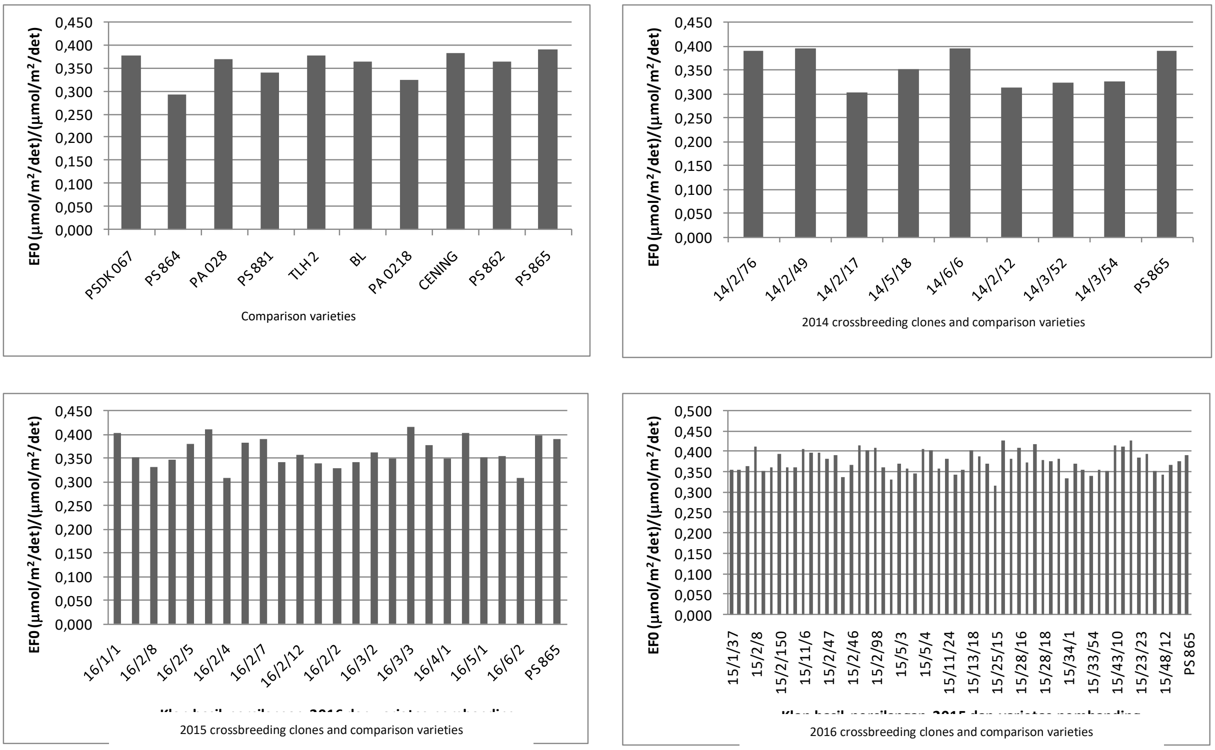

Figure 11 – Light efficiency to reduce CO_2 (EF0) (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

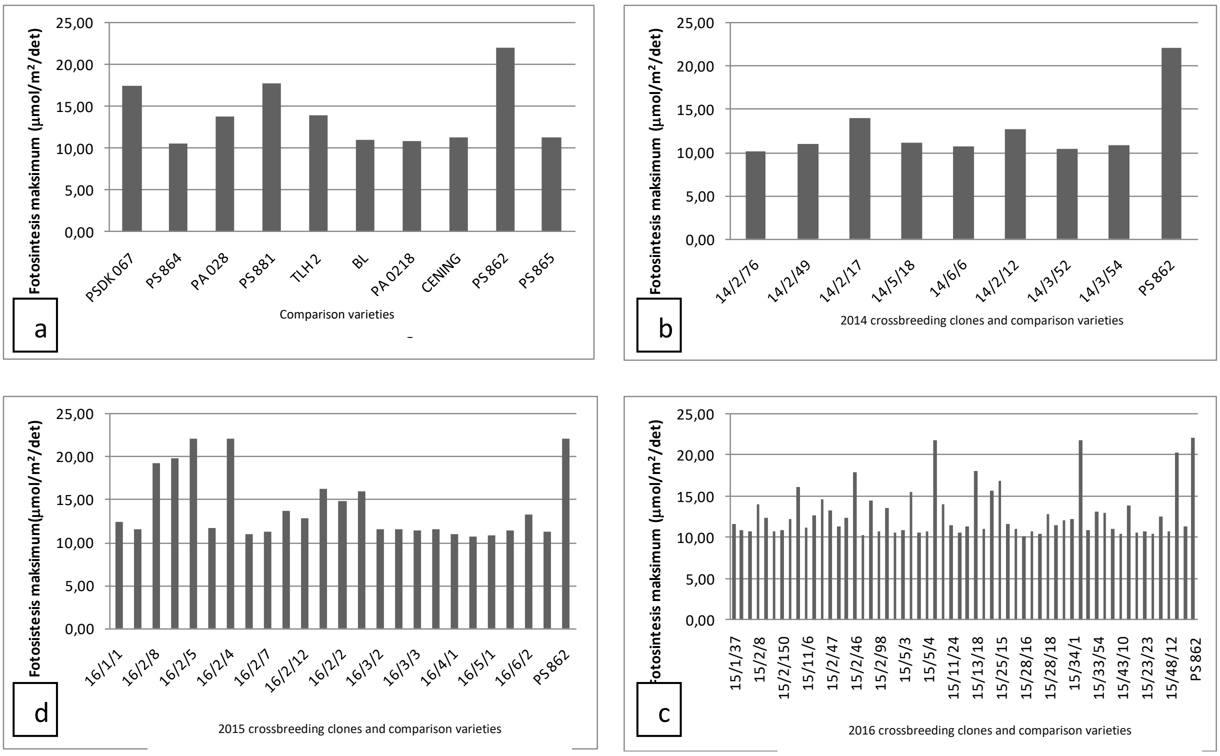

Figure 12 – Maximum photosynthetic rates of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones.

The maximum photosynthetic rate of the 2014, 2015, and 2016 crossbreeding clones varied from 10.21 mol CO_2/m^2/sec to 22.10 mol CO_2/m^2/sec, with an average of 12.89 mol CO_2/m^2/sec or a decrease of 8.10% from the parents and comparison (Figure 12). Almost all clones experienced decreased maximum photosynthetic rates. For example, the 2014 crossbreeding clones produced varied maximum photosynthetic rates, from 10.21 mol $CO_2/m^2/sec$ to 13.93 mol $CO_2/m^2/sec$, with an average of 11.35 mol $CO_2/m^2/sec$ or a decrease of 19.10% from the parent and comparison varieties. The 2015 crossbreeding clones produced varied maximum photosynthetic rates, from 10.19 mol $CO_2/m^2/sec$ to 21.84 mol $CO_2/m^2/sec$, with an average of 12.76 mol $CO_2/m^2/sec$ or a decrease of 9.08% from the parent and comparison varieties. The 2016 crossbreeding clones resulted in varied maximum photosynthetic rates, from 10.71 mol $CO_2/m^2/sec$ to 22.10 mol $CO_2/m^2/sec$, with an average of 13.74 mol $CO_2/m^2/sec$ or a decrease of 2.09% from the parent and comparison varieties. Different tobacco of Temanggung cultivars produces different photosynthetic values (Djumali, 2010).

The maximum photosynthetic rate occurs in conditions of high light intensity received by the leaves (Silva et al., 2013). Furthermore, Stirbert et al. (2014) mention that in conditions of high light intensity received by the leaves, the photosynthetic rate is largely determined by the ability of the leaves to absorb the light energy. Chlorophyll is a light-harvesting apparatus in sugarcane leaves so that there is a relationship between the maximum photosynthetic rate and the chlorophyll content of the leaves. This study obtained a positive correlation between the maximum photosynthetic rate and chlorophyll content with a correlation coefficient of 0.835; the correlation results mean that the chlorophyll content of the leaves influenced 83.5% of the maximum photosynthetic rate. The value indicates that increased maximum photosynthetic rates of sugarcane leaves of the 2014, 2015, and 2016 crossbreeding clones occurred through an increased chlorophyll content.

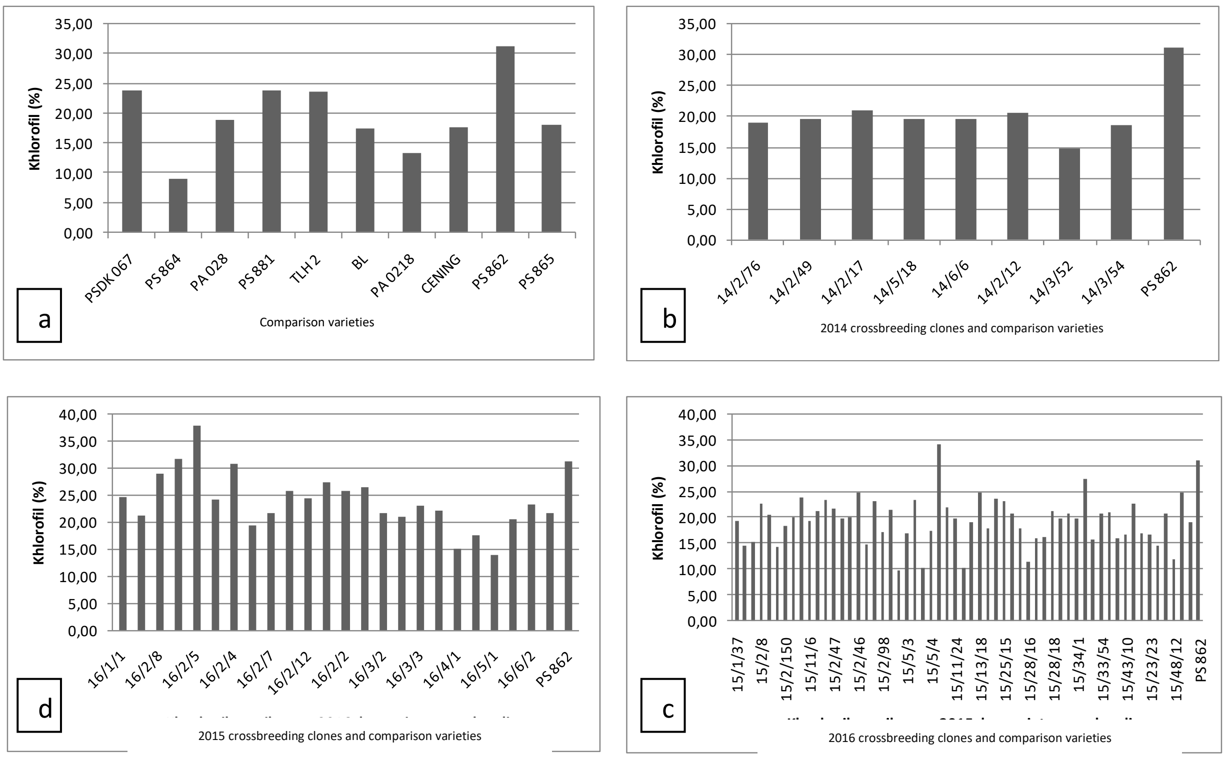

Figure 13 – Chlorophyll content of (a) the comparison varieties, (b) the 2014 crossbreeding clones, (c) the 2015 crossbreeding clones, and (d) the 2016 crossbreeding clones

The chlorophyll content of the 2014, 2015, and 2016 crossbreeding clones varied from 9.9 to 38.02, with an average of 20.51 or an increase of 3.84% from the parent and comparison varieties (Figure 13). However, not all clones experienced increased chlorophyll content. For example, the 2014 crossbreeding clones produced varied chlorophyll content, from 14.83 to 21.0, with an average of 19.13 or a decrease of 3.16% from the parent and comparison varieties. The 2015 crossbreeding clones produced varied chlorophyll content, from 9.9 to 34.3, with an average of 19.32 or a decrease of 2.18%. The 2016 crossbreeding clones resulted in varied chlorophyll content, from 13.85 to 38.2, with an average of 23.79 or an increase of 20.48% from the parents and comparison varieties.

CONCLUSION

Based on the findings and discussion presented, the following conclusions are offered. *First,* the clones resulted in varied sugar yields from 3.76 to 27.58 t/ha, with an average of 11.92 t/ha or an increase of 26.94%. *Second*, the sucrose content varied from 6.52% to 14.12%, with an average of 10.67% or an increase of 5.42%. *Third*, the extracting factors varied from 0.456 to 0.669, with an average of 0.591 or a decrease of 4.52%. *Fourth*, the juice value varied from 12.12 to 23.21, with an average of 18.02% or an increase of 10.25%. *Fifth*, productivity varied from 47.6 to 220.8 t/ha, with an average of 110.7 t/ha or an increase of 20.76%. *Sixth*, the number of stalks per meter of row varied from 5.6 to 20.7 stalks, with an average of 9.6 stalks or an increase of 15.05%. *Seventh*, cane weight varied from 0.65 kg/stalk to 2.36 kg/stalk, with an average of 1.43 kg/stalk or an increase of 3.80%. *Eighth*, stalk length varied from 140.0 cm to 283.0 cm, with an average of 212.7 cm or an increase of 13.65%. *Ninth*, stalk diameter varied from 21.0 mm to 36.4 mm, with an average of 28.1 mm or an increase of 0.83%. The relationship between cane weight and the photosynthetic rate resulted in a correlation coefficient of 0.884; this means that the photosynthetic rate determines 88.4% of the cane weight. The photosynthetic rate under the light intensity of 100 mol/m^2/sec and a temperature of 35^{o}C varied from 9.14 to 15.63 molCO_2/m^2/sec, with an average of 10.85 molCO_2/m^2/sec or a decrease by 4.27%. The maximum photosynthetic rate varied from 10.21 to 22.10 molCO_2/m^2/sec, with an average of 12.89 molCO_2/m^2/sec or a decrease of 8.10%. The chlorophyll content varied from 9.9 to 38.02, with an average of 20.51 or an increase of 3.84%. Further studies are needed to obtain clones with high productivity and drought-resistant characteristics.

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