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Soil Chemical Properties and Agronomic Response of Sugarcane (*Saccharum officinarum* L.) Due to Long Term of No-Tillage Practice and Bagasse Mulch Application

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ABSTRACT

Intensive tillage will continuously reduce soil quality, characterized by decreased soil C-organic. Low soil C-organic indicates the disturbance of soil fertility. More conservative soil management experiments have been done for seven years to restore the soil quality for sugarcane (*Saccharum officinarum* L.) productivity. This research aimed to study the effect of the tillage system, bagasse mulch, and their interactions on soil chemical properties and sugarcane agronomic response. The research was conducted on a Split Plot of five groups. The main plot was the tillage system consisting of intensive tillage and no-tillage, while the subplot was the bagasse mulch consisting of bagasse mulch and no-bagasse mulch. This study found that in sugarcane cultivation, no-tillage system was beneficial for soil P-available, sugarcane length, and sugarcane ripening; bagasse mulch was beneficial for soil C-organic and also soil P-available. The no-tillage system to increase P-available can be combined with bagasse mulch or no-bagasse mulch, but the no-tillage system combined with no-bagasse mulch increases the percentage of gap in sugarcane cultivation.

Keywords: Bagasse mulch, sugarcane, tillage systems

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is the primary raw material in the sugar industry. Sugarcane contains syrup which can be processed into sugar. Sugar cane processing into sugar also produces side products with a high economic value used as raw materials for the ethanol industry and bioenergy sources. The significant market opportunities and meet the national sugar demand make sugarcane one of the commodities cultivated, especially on a large scale, with intensive cultivation techniques.

Expansion and cultivation practices by providing optimal growth factors for sugarcane is an effort to increase sugarcane yields. One way to create optimal conditions for sugarcane growth is to provide suitable growing media by tillage. Land clearing for sugarcane cultivation involves intensive tillage. The dynamics of the soil C-organic content will occur when various land-use systems are converted into a sugarcane field. The results of Bordonal *et al.* (2017) research show that after three years of land-use change, land conversion of coffee to sugarcane decreased soil C-organic from 124.5 to 99.8 Mg C ha^{-1} (19.9%) at 0-100 cm layer and land conversion of soil C-organic stock from citrus to sugarcane was from 147.7 to 113.1 Mg C ha^{-1} (23.4%) in the 0-100 cm layer.

Intensive tillage can provide good soil conditions, but long-term intensive tillage causes a weak soil structure stability (Pires *et al.* 2017), followed by a decrease in the soil C-organic content (Six *et al.* 1999). Low soil C-organic content indicates disruption of soil chemical, physical and biological fertility because soil conditions do not provide a suitable media for roots, nutritional source, plant growth, and development, not by the potential of plants which results in a crop yields decrease.

Conservative tillage is needed to restore soil quality so that the soil can provide an ecosystem service for plant growth and productivity to maintain the sustainability of environmental and agricultural businesses. According to Busari *et al.* (2015), conservation tillage can be applied with no-tillage and organic mulch. Surendran *et al.* (2016) recommend conservation tillage combined with waste management to increase sugarcane yields and quality. According to Myers *et al.* (1994), organic residue management as mulch can increase crop productivity and fertilizer efficiency and ensure agricultural production sustainability.

Land conservation management experiments have been completed at PT GMP for seven years. The treatment consists of a no-tillage system and bagasse mulch. In the first year (2010), the no-tillage system and bagasse mulch did not significantly affect N-total content and soil acidity, but the application of bagasse mulch had a significant effect on soil C-organic content (Miura *et al.* 2013). In the second to the third years (2011-2012), the no-tillage system affected a soil C-organic increase from the previous year, especially if combined with bagasse mulch. The no-tillage system also increased soil N-total content in the second year (Pratiwi *et al.* 2013, Simamora *et al.* 2015 Widodo *et al.* 2016). In the fourth to seventh years (2014-2017), the tillage system and bagasse mulch did not significantly affect C-organic, N content, and soil acidity (Bhakti *et al.* 2017, Setiawan *et al.* 2016 Niken *et al.* 2017).

The purpose of this research is to study the effects of the tillage system and bagasse mulch application on soil chemical properties and sugarcane agronomic response.

MATERIALS AND METHODS

This research is long-term research that started in June 2010. The seventh-year experiments were

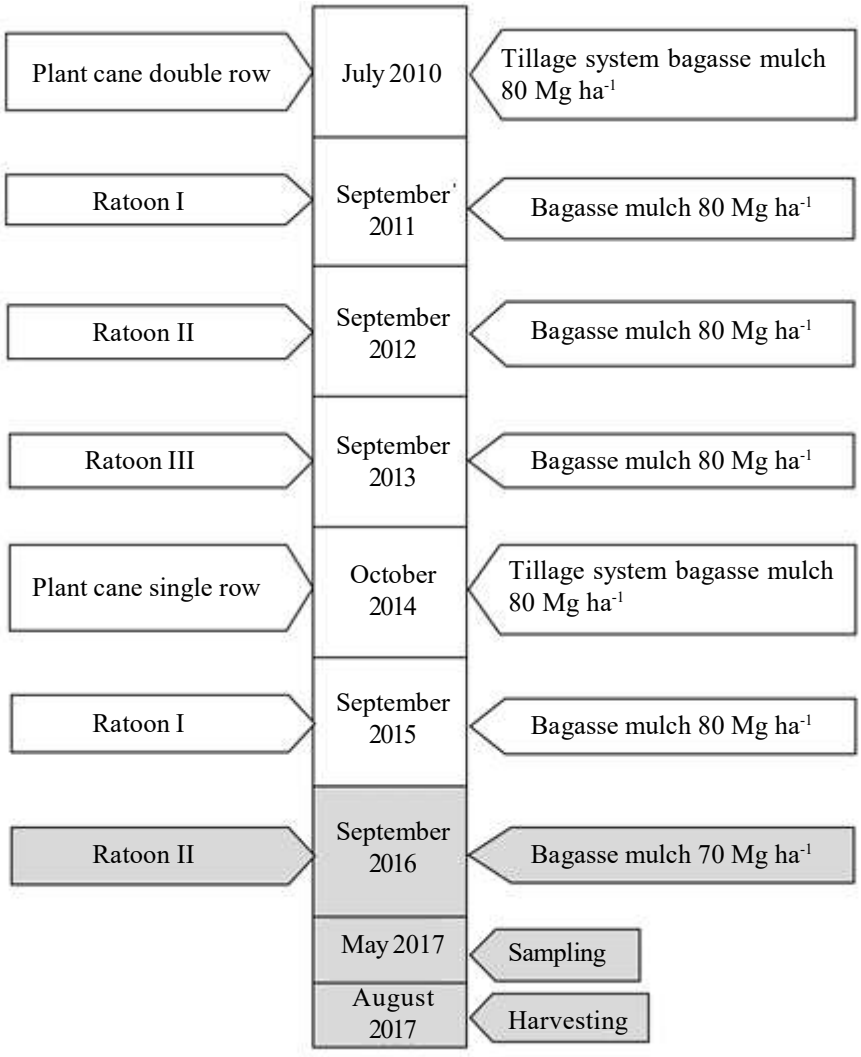

Figure 1. The History of soil tillage and mulch bagasse experiments at PT GMP.

carried out from September 2016 to May 2017. Geographically, the research was located at 4°40' S-105°13' W with an altitude of c.a. 45 m. The experimental site was located within a large area (approximately 25,000 ha) of the sugarcane plantation owned by PT Gunung Madu Plantations (GMP), Gunung Batin, Central Lampung. Soil analysis was carried out at the Soil Science Laboratory, Faculty of Agriculture, Lampung.

This research used a split-plot design with tillage as the main factor and bagasse mulch as the secondary factor. The treatments were no-tillage without mulch (NT), no-tillage with mulch (NTM), conventional tillage without mulch (CT), and conventional tillage with mulch (CTM). Each treatment was repeated across five replicate blocks. Each treatment was applied on the sugarcane cropland of 25 × 40 m and used a single row system with a row space of 150 cm. In the seventh year of this experiment, sugarcane was in the second ratoon stage of the RGM 838 variety planted in 2014 (Figure 1).

Conventional tillage treatments were carried out in land preparation for plant cane according to standard operating procedures (SOP) for land preparation activities by PT GMP (3 times each at a depth of 20 cm, 40 cm, and 20 cm). In the experimental plot of the no-tillage system, the plants were dismantled with glyphosate. Bagasse mulch treatments were applied immediately after replanting two to four weeks after harvesting in ratoons. Bagasse mulch was spread manually on the soil surface at a dose of 70-80 Mg ha^{-1}.

The application of organic matter has used a mixture of bagasse, filter cake, and bagasse ash (BBA) with a ratio of 5:3:1 at a dose of 80 Mg ha^{-1}. This organic matter was applied by spreading evenly on the soil surface a moment when plowing was carried out. While in the no-tillage system, BBA was spread evenly after planting. The chemical fertilizer application (N:P:K 120:80:8O kg ha^{-1}) was applied to each treatment immediately after planting.

Soil sampling used a mixed-method from six sample sites at each experimental plot to analyze soil acidity, C-organic, N-total, P-available, Base saturation, and cation exchange capacity. Soil sampling at each site used a soil auger to a depth of 20 cm.

Measurement and Calculation of Agronomic Aspects

Number of Harvestable Cane

Harvestable cane is sugarcane that meets the stem length requirements, and the color is not green. The cane length was counted in the middle row, and the cane along the middle row was counted. The total amount of sugarcane that can be harvested per hectare is calculated using the formula below:

$$Number\ of\ harvestable\ cane\ per\ hectare = \left(\frac{number\ of\ harvestable\ cane\ per\ row}{length\ (m)}\right) \times row\ space\ (m)$$

Ton Cane per Hectare (TCH)

Ton cane per hectare was measured from cane weight. Cane sampling was carried out by selecting two harvestable cane in the row sample. Ton cane per hectare is calculated using the formula below:

TCH= number of harvestable cane per hectare × cane weight

Rendement and Maturity Analysis

Maturity factor and rendement calculated from measuring cane Brix at three parts of the cane (base, middle and top) were used with a Refractometer. Brix describes the percent of solids dissolved in solution. If the Brix is close to zero, the cane is almost mature. Maturity analysis calculated using the formula below:

$$Maturity\ factor = \frac{base\ cane\ Brix - top\ cane}{Brix}$$

Then calculation of rendement using the formula bellow : (Evizal 2018)

$$Rendement = 0.0254 + \left(0.476 \times \frac{base\ cane\ brix + middle\ cane\ brix + top\ cane\ brix}{3}\right) \times 100\%$$

Ton Sugar per Hectare (TSH)

The formula below calculates the ton of sugar per hectare

TSH = TCH × rendement

Unharvestable cane

Unharvestable cane is young sugarcane that is not worth to be harvested. The criteria are that the color of the cane is green, and the cane height does not meet the harvest criteria (Evizal 2018). Unharvestable cane was counted along with the row sample. Calculation of the proportion of unharvestable cane following the formula below:

$$Unharvestable\ cane\ (\%) = \frac{number\ of\ unharvestable\ cane}{number\ of\ unharvestable\ cane + number\ of\ harvestable\ cane} \times 100$$

Gap

A gap is an empty row along ≥ 50 cm. Gap counted along the row sample and calculated using the formula below:

$$Gap\ (\%) = \frac{Gap\ length\ total}{row\ length} \times 100$$

The soil was sifted using a 5 mm soil sifter and then analyzed to measure the soil C-organic content (Walkley and Black), N-total (Kjehdahl), P-available (Bray 1), base saturation (NH4OAc 1 *N* pH 7), pH (H_2O) and cation exchange capacity (NH4OAc 1 *N* pH 7). The procedure referred from the Management of Soil and Plant Analysis by Thom and Utomo (1991).

The data were analyzed by analysis of variance (ANOVA) to see the treatment effect on the measured variables. If the treatment effect is significant on the measured variable, the average was tested by the Least Significant Difference (LSD) test at the significant level of 5 %.

RESULTS AND DISCUSSION

The Effect of Tillage System and Bagasse Mulch on Soil Chemical Properties

Soil Acidity

The results of the ANOVA for soil acidity showed that the tillage system, bagasse mulch, and their interaction had no significant effect on soil pH. Generally, the no-tillage system resulted in slightly lower soil pH than intensive tillage, although this was not statistically significant (Table 1). Soil conditions also generally show a low pH (acidic soil).

The results of research by Rasmussen (1999) and Kumar and Yadav (2005) showed the same results, where differences in soil management systems had no significant effect on soil acidity. Meanwhile, Rahman *et al.* (2008) results showed that the no-tillage system resulted in lower soil pH compared to the intensive tillage system. The accumulation of organic matter can cause the low pH of the soil in a no-tillage system, thereby increasing the concentration of electrolytes and decreasing pH (Rhot, 2000; Rahman *et al.* 2008).

According to Busari *et al.* (2015), tillage systems do not affect soil acidity directly but depend on climate, soil type, and other management. Many factors influence soil acidity, so applying a no-tillage system and the application of bagasse mulch cannot improve soil acidity conditions. Ultisols classified as acid soils are a problem for the cultivation land and N fertilization in cultivation techniques also contributes to the increased soil acidity. PT GMP applied liming using dolomite to increase soil pH to overcome this problem. Liming is an effort to improve pH directly and quickly. However, this is only temporary. Liming is always done when preparing the planting area to provide an excellent growing medium for the growth and development of sugarcane plants.

Soil C-Organic Content

The results of ANOVA show that the tillage system had no significant effect on soil C-organic content, and bagasse mulch was very significant in influencing soil C-organic content. However, bagasse mulch combined with a tillage system did not significantly influence soil C-organic content (Table 1). The average soil C-organic content on the plot applied with bagasse mulch is 1.46%, whereas no-mulch treatment is 1.20% (Table 2).

According to Cherubin et al. (2015), the quality of organic matter is an essential indicator in assessing

Table 1. The summary of ANOVA for soil chemical characteristics in the long-term tillage system and bagasse mulch experiments.

Treatment	pH H_2O	C-organic (%)	N-total (%)	P-available (g kg^{-1})	CEC (cmol kg^{-1})	Base Saturation (%)
CT	5.22 ± 0.19	1.12 ± 0.08	0.06 ± 0.00	40.97 ± 4.87	10.25 ± 1.28	20.82 ± 3.22
CTM	5.13 ± 0.21	1.49 ± 0.36	0.07 ± 0.02	50.97 ± 7.51	10.45 ± 3.25	19.58 ± 3.16
NT	5.03 ± 0.14	1.27 ± 0.27	0.07 ± 0.01	52.86 ± 6.96	10.52 ± 2.24	20.89 ± 3.42
NTM	5.06 ± 0.45	1.43 ± 0.15	0.07 ± 0.02	51.16 ± 12.22	11.49 ± 2.73	19.91 ± 5.21
Source of diversity	……P-value……					
T	-	0.58	-	0.00	0.28	0.85
M	-	0.00	-	0.04	0.34	0.31
T × M	-	0.20	-	0.00	0.52	0.90

Note: Significant if $P < 0.05$ and very significant if $P < 0.01$; CT (conventional tillage without mulch); CTM (conventional tillage with mulch); NT (no-tillage without mulch) and NTM (no-tillage with mulch). The data were not analyzed by analysis of variance because after being transformed, the data was still not additive.

Table 2. The results of the LSD test for soil C-organic content on the long-term tillage system and bagasse mulch experiment.

Treatment	Organic-C (%)
Bagasse mulch	1.46 a
No-bagasse mulch	1.20 b
LSD 5 %	0.17

Note: the values followed by the same notation in the same column are not significantly different

the environmental sustainability of sugarcane plantations. The only way to increase the C-organic content of the soil is by providing input of organic matter, in the form of fresh organic matter, manure, or compost, naturally through accumulated litter or input from human in the form of organic matter. Bagasse is one organic mulch. In addition to covering the soil to maintain the dynamics of organic matter in the soil, bagasse mulch will also decompose and contribute to C-organic soil, as happens on the plot that is treated with bagasse mulch. Bagasse mulch treatment resulted in 0.26% higher C-organic soil than the without mulch treatment. Soil C-organic content increased by 0.26%, contributing 5,200 kg ha^{-1} of C-organic in sugarcane cultivation land.

Intensive tillage is carried out to provide good soil conditions for root growth and development. However, intensive tillage causes soil disturbances that directly impact decreasing the level of soil aggregation. The destruction of soil aggregates increases the Number of soil pores, thereby increasing aeration and accelerating the mineralization rate of organic matter. Other factors such as soil type, climate, and tillage only affect the dynamics of C-organic in the soil (Balesdent *et al*. 2000).

Nitrogen Total

The results of ANOVA show that the tillage system, bagasse mulch, and interactions of the tillage system and bagasse mulch do not significantly affect soil N- total content soil. Generally, the N-total content in each treatment is same relatively. Nitrogen total for the four treatment combinations is 0.06-0.07 % (Table 1).

Nitrogen is one of the essential macronutrients needed by plants to form amino acids, but the availability of nitrogen in the soil is minimal. The most abundant source of N is in the atmosphere in a form that cannot be directly utilized by plants, while the N element in the soil is volatile (Handayanto *et al.* 2007). Besides that, the higher C: N ratio of bagasse which is about 80:1, causes N-immobilization by soil microorganisms. Bagasse only provides a little of N, especially in the early years of use. Therefore, the bagasse mulch cannot increase the N content in the soil. According to Vallis (1996), reducing N fertilizer use with N-mineralization from sugarcane trash needs a long time, which is about 20 years.

Phosphorus Available

The result of ANOVA for phosphorus available shows that the tillage system and bagasse mulch significantly affected P-available content. In addition, there is an interaction between the tillage system and bagasse mulch to influence the soil's P-available content (Table 1). The intensive tillage treatment combined with no-bagasse mulch treatment for seven years produced the lowest P-available content (40.97 g kg^{-1}), while the P-available content between intensive tillage combined with bagasse mulch treatment, no-tillage treatment, and no-tillage combine with no-bagasse mulch treatment are not significantly different, each 50.97; 52.86 and 51.16 g kg^{-1} (Table 3). This result means soil conservation system by no-tillage, bagasse mulch, or a combination of both can increase soil P-available content in sugarcane cropland.

High P fixation is a problem in Ultisol; therefore, the addition of fresh organic matter, manure, or

Tabel 3. The results of the LSD test for P-available content on the long-term tillage system and bagasse mulch experiments.

Treatment	P-available (g kg^{-1})
Conventional tillage x Bagasse mulch	50.97 a
Conventional tillage x No-bagasse mulch	40.97 b
No-tillage x Bagasse mulch	51.16 a
No-tillage x No-bagasse mulch	52.86 a
LSD 5 %	5.66

Note: the values followed by the same notation in the table were not significantly different

compost is necessary. Nurida *et al.* (2007) show that fraction changes of soil organic matter affect P available content indirectly. Bagasse mulch is one example of fresh organic matter inputs. Fresh organic matter will decompose and produce humic that is reactive to P sorption, so that can reduce P fixation (Nurjaya 2016).

Aggregate stability directly impacts organic matter dynamics, while a decrease in soil porosity due to a no-tillage system will reduce the rate of organic matter mineralization. There is no physical disturbance to the soil in the no-tillage system, which forms soil aggregate stabilization gradually (Chao-su *et al.* 2016). The decomposition rate control on the no-tillage system can increase the soil P-available.

Cation Exchange Capacity and Base Saturation

The results of the ANOVA showed that the tillage system, bagasse mulch, and the interaction of the two treatments had no significant effect on the cation exchange capacity of the soil. In general, it can be seen that the cation exchange capacity of soil with the no-tillage system combined with bagasse mulch has the highest cation exchange capacity (11.49 cmol kg^{-1}) but is not significantly different from other treatments statistically (Table 1).

One of the soil's chemical properties related to the availability of nutrients for plants and is an indicator of soil fertility is Cation Exchangeable Capacity (CEC). The CEC depends on the amount of soil colloid, organic colloid in humus, or inorganic colloid in clay, which has a negative charge. The CEC of humus is more significant than that of clay colloids. The negative charge of the soil colloid will be exchanged by cations that are adsorbed by the soil colloid (Schoonheydt and Johnston 2013) and, under certain conditions, can also be released. Other soil particles also play a role in CEC, but they have a weak CEC.

Clay content is related to soil texture, and soil development conditions influence soil texture. In addition, the problem with intensive agricultural soils in the wet tropics such as Sumatra is the vertical movement of clay due to intensive soil cultivation and infiltration so that the clay accumulates in the sub-soil. Intensive agricultural soils in the tropics also make the decomposition of the organic matter very fast (Sonon *et al.* 2017).

Application of no-tillage should be able to suppress the occurrence of soil aggregate damage and reduce the vertical movement of clay. In the no-tillage system, there is an improvement in the stability of soil aggregates so that there is no soil aggregate breaking activity which results in the release of clay particles and leaching of clay particles, and vertical movement of clay through infiltration (Banuwa 2013). Another advantage of using mulch, according to Busari *et al.* (2015) can play a role in protecting the soil from the direct impact of rain splashes. According to Kader *et al.* (2017), in addition to suppressing soil quality degradation through the prevention of surface runoff, mulch can also maintain soil structure so that the stability of organic matter is maintained and maintains the microclimate on the soil surface.

The results of the ANOVA also showed that the tillage system, bagasse mulch, and the interaction of the two treatments had no significant effect on soil base saturation. In general, it can be seen that the base saturation of each treatment is relatively the same. Base saturation is closely related to cation exchange capacity and soil acidity. Following soil acidity and soil CEC, each treatment in this experiment is not significantly different (Table 1).

Base saturation describes the cation exchange capacity of the soil to adsorb base cations. Soils with high CEC do not always have high base saturation because it depends on the type of cation being adsorbed, base cation such as $Ca^{2+,}$ $Mg^{2+,}$ K^{+}, dan Na^{+} or acid cation H^{+} and Al^{3+} that significant of cations adsorbed on the soil colloids. This makes base saturation closely related to soil pH (Sonon *et al.* 2017). In acidic soils such as in this research, the cation exchange site absorbs many acid cations so that the soil pH and base saturation are also low.

The Effect of Tillage System and Bagasse Mulch on Agronomic Response

Cane Length

Plant length is the most easily observed plant growth indicator. The results of ANOVA show that the tillage system significantly affected the cane length, while bagasse mulch and their interaction did not affect cane length significantly (Table 4). The no-tillage system for seven years results in a longer cane than the intensive tillage system 249.15 and 225.40 cm, respectively (Table 5). The same results also occurred in Jayasumarta's (2012) research which showed that soybean plants grown with a no-tillage system produced the best plant length compared to minimum and intensive tillage, while on soybean production aspects such as Number of pods, dry seed weight, and dry weight of 100 seeds of plants did not have a significant effect.

The no-tillage system is an effort to improve soil physical properties closely related to aggregate

Table 4. The summary of ANOVA for sugarcane growth aspects in the long-term tillage system and bagasse mulch experiment.

Treatment	Cane length (cm)	Number of cane (cane ha^{-1})	Unharvestable cane (%)	Gap (%)
CT	224.0 ± 29.81	54.263 ± 9.585	33.07 ± 14.83	22.08 ± 9.30
CTM	226.8 ± 24.02	53.628 ± 4.590	30.38 ± 4.99	26.36 ± 10.45
NT	247.1 ± 27.97	59.194 ± 13.352	26.27 ± 5.39	33.23 ± 7.67
NTM	251.2 ± 23.79	49.328 ± 16.902	26.46 ± 10.23	25.69 ± 10.51
Source of diversity	……..……P-value…….……..			
T	0.04	0.94	0.17	0.06
M	0.74	0.19	0.82	0.54
T x M	0.96	0.25	0.88	0.04

Note : Significant if P < 0.05 and very significant if P < 0.01; NT (no-tillage without mulch), NTM (no-tillage with mulch), CT (conventional tillage without mulch), and CTM (conventional tillage with mulch).

stability and soil porosity, thus increasing groundwater retention and reducing surface flow, thereby supporting root growth (Chaosu *et al.* 2016). Intensive tillage results in soil aggregate destruction, decreasing aggregate stability and increasing the Number of soil micropores and macropores (Rahman *et al.* 2008). In addition, during the initial planting period, the soil treated with intensive tillage is prone to erosion and leaching. Warm temperatures in the tropics also result in high degradation rates of organic matter and soil evaporation in intensive tillage systems (Utomo 2015), whereas in the vegetative phase, sugarcane requires enough water to support plant growth.

Number of Harvestable Cane

The results of ANOVA for the Number of harvestable cane show that the tillage system, bagasse mulch, and their interactions did not influence the Number of harvestable cane statistically (Table 4). However, generally bagasse mulch application on a no-tillage system impact to lowest Number of harvestable cane, which is 49.328, compared to no-bagasse mulch, although it is not significant statistically (Table 4).

Besides having a beneficial effect by increasing soil C-organic content, Ramburan *et al.* (2013) research show that mulch trash treatment significantly decreased sugarcane yield. According to Ramburan and Nxumalo (2017), mulch gives an uncertain response to sugarcane because it is influenced by complex factors such as season, region, planting time, plant phase, and cultivar. This is a complex interaction between genetics, environment, and management.

The Number of harvestable cane is the total of cane according to the criteria for further processing in the sugar factory. According to Evizal (2018), not all sugarcane will grow to produce harvestable cane; some will grow slowly, and their growth will not catch up with other cane growth so they will become unharvestable cane.

Unharvestable Cane and Gap

The results of ANOVA for a percentage of unharvestable cane show that the tillage system, bagasse mulch, and their interactions were not significant in influencing the percentage of unharvestable cane (Table 4). Nevertheless, the no-tillage system with bagasse mulch or without bagasse mulch gave the lowest percentage of unharvestable cane compared to the intensive tillage system (Table 4). In the no-tillage system, the percentage of the unharvestable cane on the plot that gave bagasse mulch and did not give bagasse mulch was 26.46% and 26.27%, respectively. However, the no-tillage system, bagasse mulch, and their interactions were not statistically significant in influencing the percentage of unharvestable cane (Table 4).

The results of the ANOVA gap percentage shows that the tillage system and bagasse mulch

Table 5. The results of the LSD test for cane length on the long-term tillage system and bagasse mulch experiment.

Treatment	Cane length (cm)
No-tillage	249.15 a
Conventional tillage	225.40 b
LSD 5 %	0.74

Note: the value followed by the same notation in the same column are not different significantly

Table 6. The results of the LSD test for the percentage of the gap in the long-term tillage system and bagasse mulch experiment.

Treatment	Gap (%)
Conventional tillage x Bagasse mulch	26.36 b
Conventional tillage x No-bagasse mulch	22,08 b
No-tillage x Bagasse mulch	25.69 b
No-tillage x No-bagasse mulch	33,23 a
LSD 5 %	5.66

Note: the values followed by the same notation in the table are not different

were not significant in influencing the gap percentage, but the interaction between the tillage system and bagasse mulch significantly affected the gap percentage (Table 6). The no-tillage with no-bagasse mulch treatment produced the highest gap percentage, 33.23% (Table 6). The lowest gap percentage is in the intensive tillage and no-bagasse mulch treatment (Table 6).

The data shows that the no-tillage system can reduce late sugarcane growth. Aggregate stability improvement in the no-tillage system increases the soil water binding, especially around the roots area (Chaosu *et al.* 2016). This is beneficial, especially in sugarcane's vegetative phase, which requires sufficient water conditions for ratoon germination.

The Effect of Tillage System and Bagasse Mulch on Sugarcane Yields

Maturity Factor and Rendement

The results of ANOVA for maturity factors show that the tillage system had a significant effect on the maturity factor (Table 8). The intensive tillage system produced a higher maturity factor than the no-tillage system. The maturity level scoring by SOP of PTPN VII in Evizal (2018) shows that the sugarcane maturity level in all treatments is mature entirely at eight months.

The lower maturity factor in the no-tillage system indicates the sugarcane planted in the no-tillage system has faster maturity than on intensive tillage. This is caused by higher soil bulk density in the no-tillage system, so the roots' penetration is limited and causes stress conditions for plants. According to Osunbitana *et al.* (2005), soil bulk density increases with decreasing levels of soil manipulation during land preparation activities. In addition, soil bulk density also positively correlates with soil penetration. This condition results in a problematic root penetration in a no-tillage system, so plants are stressed due to limited root penetration.

However, the analysis of variance for sugarcane yield results shows that the tillage system, bagasse mulch, and interactions did not significantly influence sugarcane yield. Generally, bagasse mulch treatment provides a lower yield even though it is not statistically significant. According to Ramburan and Nxumalo (2017), mulch gives an uncertain

Table 7. The summary of ANOVA for sugar cane production aspects in the long-term tillage system and application of bagasse mulch experiment.

Treatment	Maturity factor	Rendement (%)	TCH (Mg ha^{-1})	TSH (Mg ha^{-1})
CT	0.10 ± 0.09	7.42 ± 1.22	123.03 ± 30.44	9.42 ± 3.33
CTM	0.18 ± 0.16	6.84 ± 0.48	133.19 ± 21.14	9.10 ± 1.60
NT	-0.01 ± 0.12	7.83 ± 0.77	152.71 ± 29.01	11.93 ± 2.51
NTM	0.07 ± 0.09	7.26 ± 0.69	142.01 ± 48.53	10.12 ± 3.27
Source of diversity	……P-value……			
Tillage	0.03	0.23	0.13	0.07
Bagasse mulch	0.09	0.11	0.94	0.30
T x M	0.95	0.99	0.29	0.33

Note: Significant if P < 0.05 and very significant if P < 0.01; NT (no-tillage without mulch), NTM (no-tillage with mulch), CT (conventional tillage without mulch) and CTM (conventional tillage with mulch) TCH : Ton cane per hectare, TSH : Ton Sugar per hectare.

Tabel 8. The results of the LSD test for sugarcane maturity factor on the long term tillage system and bagasse mulch experiment.

Treatment	Maturity Factor
Conventional tillage	0.14 a
No-tillage	0.03 b
LSD 5 %	0.1

Note: the values followed by the same notation in the same column are not different.

response to sugarcane because complex factors influence it. Sugarcane was eight months old at the observation, so there were three months to process sucrose formation in cane. In addition, sugar cane yield increase will also occur with cane ripener application by PT GMP one month before harvesting.

So at the harvesting time, the sugar cane is expected to produce higher yields.

Sugarcane Yields

The results of the ANOVA showed that the tillage system, bagasse mulch, and their interactions did not significantly affect the production of sugarcane statistically. Generally, no-tillage systems resulted in higher cane and sugar production than intensive tillage. Although it was not statistically significant, the no-tillage system for sugarcane productivity was more profitable in the no bagasse mulch (Table 7).

Mulch gives an uncertain response to sugarcane. This is caused by many factors such as season, region, planting time, plant phase, and cultivar (Ramburan and Nxumalo 2017). The results of Ramburan *et al.* (2013) research showed that the application of mulch was very significant in reducing sugarcane yields. In addition, plant growth and development respond to many complex factors. Besides the internal factors, such as the environment, external factors also determine plant growth and development.

Jayasumarta's (2012) research showed that soybean growth was better in a no-tillage system, but in production aspects such as the number of pods per plant, dry weight of seeds per plant, and dry weight of 100 seeds did not have a significant effect. In this research, although not significant, seven years without tillage treatment gave a positive response to sugarcane yields. The no-tillage system reduces production costs, making it more economical, especially in large-scale cultivation. No-tillage systems also provide the environmental benefits of providing sustainable natural resources to agricultural enterprises.

Improving soil conditions with a system without tillage and bagasse mulch is not instant. It takes a long time for the soil to form new soil stability conditions to produce a good response for plant growth. The application of tillage systems and the application of bagasse mulch for seven years has not resulted in significant changes in soil conditions in several aspects of the soil, so it has not supported plant growth and development to produce plant agronomic responses that have an impact on a significant increase in sugar production.

CONCLUSIONS

The no-tillage system was practical for increasing P-available in sugarcane plantations, producing longer cane, and providing an earlier response to sugarcane ripening compared to intensive tillage.

The application of bagasse mulch was practical to increase soil C-organic and P-available in sugarcane cropland.

By combining a no-tillage system with bagasse mulch or no bagasse mulch, soil conservation can increase the available P content. However, applying a no-tillage system with no-mulch produces the highest gap percentage.

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