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Urea Application to Enhance Sugarcane Trash Decomposition: A Field Test in PTPN VII of Cinta Manis District in South Sumatera

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Abstract

Sugarcane harvest results in plant residues, consisting of leaves, stems and roots nearly 20 ton ha^{-1}. The plantation of PTPN VII in Cinta Manis District applied urea with a dosage of 5 kg ha^{-1} but the result was not effective. There is a potential to try a higher dosage of urea to enhance trash decomposition. This research aims to evaluate urea application on biomass decomposition. This research was conducted on the Plot 07 Rayon 3 of PTPN VII, District of Cinta Manis at Ketiau, Lubuk Keliat of Ogan Ilir, South Sumatra, using Split Plot design. Main plot is trash sampling time and subplot is urea dosage with three replicates. ANCOVA was used for soil data. The rate of decomposition of the litter was calculated by the change in the initial condition of research with each week on observation resulting in decomposition rate graphs. Urea application at 10 kg ha^{-1} reduced C/N of the litter ratio to almost 21:1 and was followed by the highest total nitrogen increase to 0.18%, while the highest organic carbon decline for urea treatment of 6 kg ha^{-1} amounted to 13.78%. In conclusion, higher rate of urea application is still required to enhance sugarcane litter decomposition.

Keywords: biomass decomposition; nutrient release; sugarcane litter; urea application

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INTRODUCTION

Sustainable production of sugarcane is considerably affected by plant cane and ratoon, tillage, fertilization and climate. Yield gap is somewhat great between plant cane and ratoon, and thus, such efforts should be taken to increase ratoon yield (Surendran et al., 2016). Land preparation without trash burning is also important to maintain soil quality for the subsequent planting and harvest (Graham and Haynes, 2006). Warm climate may lead to such condition of water shortage for sustainable growth of sugarcane (Meier and Thorburn, 2016; da Luz et al., 2019), particularly the impact on nitrogen dynamic (Thorburn et al., 2005).

In the sugar industry, sugarcane litter processing is occasionally done by burning (Graham and Haynes, 2006; Meier and Thorburn, 2016). Burning may result in land degradation in the form of changes in physical properties of the soil, decreased soil fertility, loss of soil biota, global warming, the danger to residential settlements around plantation land and can cause air pollution and respiratory problems (Rípoli et al., 2000; Sugandi et al., 2013). In 2017, PTPN VII's production reported that 1 ha of land produced 70-80 tons of sugarcane, 50 tons of sugarcane was ready to be milled, the rest in the

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form of sugarcane litter was estimated to reach more than 20 tons ha^{-1}.

Sugarcane harvest residue can provide nutrients for plants but cannot be absorbed directly by plants (Fortes et al., 2013). Sugarcane litter must go through a decomposition process before absorbed by plants (Fortes et al., 2012; Dietrich et al., 2017; Rodríguez-Machín et al., 2018). Based on the research conducted by Quirk and Zwemer (2007) in their trial at the McLeods Creek site, the rate of decomposition of organic matter can be significantly accelerated by the application of urea fertilizer sprayed onto the surface of the material in small quantities (1.5-3 kg ha^{-1}). Shortening the decomposition process from 24 weeks to 8 weeks by breaking down organic matter is sufficient to allow conventional planting in shorter periods. The application of urea can provide a source of nitrogen that can increase nitrogen levels to provide food sources for microbes (Van Soest, 2006; Rimartika, 2017). The efficiency of Nitrogen use by the sugarcane ratoon was 21% and by sugarcane straw was 9% (Gava et al., 2005).

PTPN VII Cinta Manis District has applied urea fertilizer at a dosage of 5 kg ha^{-1} but in the field it has not been able to accelerate the process of litter decomposition sufficiently, so there is a potential to apply a larger dosage of urea in order to accelerate the rate of decomposition. In fresh sugarcane litter has a high C/N ratio and results in low microbial activity so it requires a long time for decomposing the material. A field research in India (Surendran et al., 2016) and in Brazil (Rachid et al., 2016) proved that when the C/N ratio is higher, the nitrogen in the soil becomes low and affects microbial activity because nitrogen is a food source for microbial compositions. In this case, accelerating the rate of decomposition can be done both physically and chemically (Hartemink, 2008). Physical accelleration of decomposition process is done by chopping into smaller pieces. Meanwhile, chemical acceleration of decomposition is performed by reducing the C/N ratio in sugarcane litter using a mixture of materials that have high Nitrogen content to provide a food source for microbes. Therefore, the researchers tried to use urea with various dosages to find the right dosage of urea in accelerating the process of decomposition of sugarcane litter on the land of PTPN VII Cinta Manis District. The rate of decomposition can be promoted by adding various dosages of urea (Wood, 1991; Vallis et al., 1996; Awe et al., 2015). The purpose of this study was to evaluate and compare the application of urea in sugarcane litter to the availability of Nitrogen in accelerating the decomposition process.

We hypothesized that the addition of urea with the highest dosage of sugarcane litter will affect the rate of decomposition and decrease the C/N ratio of ingredients and the addition of various urea dosages within 6 weeks will have the highest effect in increasing the decomposition rate and decrease the C/N ratio.

MATERIALS AND METHOD

This research was carried out in plot 07 Rayon 3 of PTPN VII in Cinta Manis District, Ketiau Village, Lubuk Keliat Sub-district, Ogan Ilir Regency, South Sumatra. Soil and plant analyses were carried out in the Soil Chemistry Laboratory, Faculty of Agriculture, Universitas Sriwijaya and Soil Laboratory of PTPN VII Cinta Manis, from October to December 2018.

The field experiment used Split Plot design in time consisting of 4 litter sampling time (before treatment and 2, 4 and 6 weeks after treatment) as the main plots and 6 urea dosage (0-10 kg ha^{-1}) as the subplots and 3 replications. A composite soil sampling was conducted to 20 cm depth at initial time (before urea application) and after 6 weeks. Soil samples were analysed for organic carbon, total nitrogen and C/N ratio. Likewise, composite litter samples were also collected randomly from three subsamples by using a 25 cm x 25 cm rectangular bamboo tool. The trial plot measures 126 m x 100 m were divided into three blocks. Each urea dosage was mixed with 19.15 liters of water in the knapsack sprayer, then sprayed on the litter surface based on the specified plot (Figure 1) by following each track. In one plot, there were 4 planting trenches.

Litter samples were taken to the PTPN VII soil laboratory, labeled and then put in oven for 24 hours at 105°C. Next, the litter samples were cooled, then chopped with a chopper machine to produce materials like powder. After being powdered, the samples were composited with a ratio of 1:1:1 and then were put into a sample glass and stirred evenly. Soil samples were taken to a soil laboratory and then air-dried using a tray for

5-7 days, and then sieved with a 5 mm sieve and composited with a ratio of 1 : 1 : 1. The samples were afterwards placed into a sample glass and stirred evenly.

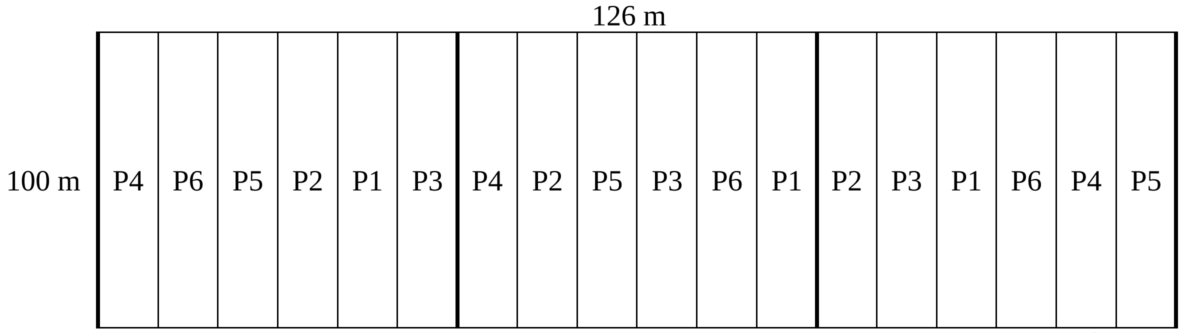

Figure 1. Research plots (P0, P1, P2, P3, P4 and P5 are urea at 0, 2, 4, 6, 8 and 10 kg ha^{-1} respectively)

The analyses includes the chemical properties of litter (Menon, 1973) namely C-organic (Walkley-Black dichromate titration), N-total (micro Kjeldahl digestion) and C/N litter ratio (counting). The analyses were conducted twice, the beginning of the study before given urea and at the last observation after the application of urea. Soil samples were directly prepared for analyses in the laboratory. The soil analyses include (Menon, 1973) soil pH (glass electrode), C-organic (Walkley-Black dichromate titration) and N-total (micro Kjeldahl digestion).

To find out the effects of urea application on sugarcane litter, the data were analyzed using a Split Plot in time analysis (Steel and Torrie, 1981). The linear additive model is:

$$X_{yk} = \mu + \rho_i + \alpha_j + \delta_{ij} + \beta_k + (\sigma\beta)_{jk} + \varepsilon_{ijk}$$

Where:

μ = Mean value
ρ_i = Effect of repetition
α_j = Effect of main plot (time)
δ_{ij} = Mainplot error (time)
β_k = Effect of subplot (urea dosage)
$(\alpha\beta)_{jk}$ = Effect of interaction
ε_{ijk} = Error of subplot

Meanwhile, the soil observations in this study applied the Analysis of Covariance (ANCOVA). This method actually combines Analysis of variance (ANOVA) and linear regression, taking a continuos response as covariate. In this study, the covariate is the initial value of soil data. The structure of treatment remains the same, involving 6 treatments of urea application, ranging 0-10 kg ha^{-1} with 3 replicates.

X Preliminary data before receiving any treatment
Y Final data of observation after being treated at 6 weeks

Using the model proposed by Steel and Torie (1981), the linear additive model of ANCOVA with completely randomised block is:

$$Y_{ij} = \mu + \tau_i + \rho_j + \beta\left(X_{ij} - \bar{x}\right) + \varepsilon_{ij}$$

RESULTS AND DISCUSSION

Morphology of sugarcane litter

Sugarcane litter has been decomposing for 6 weeks or 44 days as noted from its physical appearance (Figure 2). The initial litter was 1-week old ratoon, in which litter was in the form of undecomposed leaves. In the following weeks, a gradual change in form and shape of sugarcane trash from the field and after drying in the oven was noted. The quality of the initial litter has a significant role, presumably because the lignin content in the sugarcane litter can also affect the rate of decomposition rate. Lignin can be a predictor of litter decomposition rate (Rahman et al., 2013). Lignin concentration is more influential compared with other chemical concentrations in determining litter decomposition rate. High lignin content will inhibit the decomposition process because lignin is a complex compound that is difficult to decompose by soil microorganisms (Aprianis, 2011). Sugarcane bagasse may contain lignin around 19-22% (Karp et al., 2013). However, lignin content is not determined in this study.

Figure 2. Forms of sugarcane litter at initial time and after 2, 4 and 6 weeks in the field

Litter decomposition cannot be separated from the existing environmental conditions. This study was supported by daily rainfall conditions at the study site. At the beginning of the study, rainfall was relatively low and in the second week, there was almost no rainfall. However, in the fourth and sixth weeks, the rainfall was relatively high. According to Dietrich et al. (2017) and Jayanti (2017), rainfall and temperature have a strong relationship with the process of litter decomposition, so that if rainfall and temperature increase, the litter decomposition rate will also increase. The highest rainfall took place in November 2018, where it was almost rainy every day. Within 30 days, it rained for 19 days, with relatively high rainfall. It is found that rainfall plays a role in creating an environment that supports the life or activity of soil microorganisms. Possible use of sugarcane straw has been reviewed (Leal et al., 2013). Besides its potential use as feedstock for energy production, there are several possible agronomic benefits of the straw blanket left on the ground such as soil protection against erosion, increase in soil organic carbon content, inhibition of weed growth, nutrient recycling and reduction in soil water losses. The amount of straw left in the field depends on the local conditions, agricultural practices, characteristics of the straw and intended final use.

Straw management in the field is important for maintaining sugarcane yield (de Aquino et al., 2017). Field managements with burned cane, total removal of the straw, or keeping 25% of straw result in low number of tillers, leaf area index, stem diameter and productivity of sugarcane ratoons, under water stress conditions. Whereas, keeping 50% of straw mulch is enough to improve the growth and yield of sugarcane with drought occurrences, while the remaining 50% can be used for second generation of ethanol production or electricity without damaging the crop yield.

Changes of organic carbon and total nitrogen in sugarcane litter

Sugarcane litter is an organic material that in natural conditions will decompose due to the activity of decomposition microorganisms that develop in it, but the addition of a short composer can accelerate the decomposition process. Giving urea for 6 weeks can affect the rate of litter decomposition. Table 1 shows the organic carbon content decrease with time significantly, while total nitrogen somewhat increased with time. Insignificant interaction means that the pattern between urea levels was similar across time.

Table 1. Analysis of variance summary for litter quality

Source of variance	C-organic	N-total	C/N ratio
Block	1.11^{ns}	0.51^{ns}	0.02^{ns}
Time	8.16*	4.42^{ns}	6.09^{ns}
Urea application	1.07^{ns}	0.96^{ns}	0.41^{ns}
Interaction	1.13^{ns}	0.45^{ns}	0.21^{ns}

Note: * = significantly different; ns = not significantly different

This is presumably due to C-organic matter decomposed as food in microorganisms and decomposed into CO_2 into the air so that the amount is reduced. Based on the average value of litter organic carbon as presented in Table 2, the initial content had a very high C-organic value that was the overall average of each treatment at the beginning of the study of 52.29%. This would have a significant effect on the C-organic content in the following week, where at the beginning of the study, treatment was not given. After being given almost all treatments, C-organic content would decrease. The highest decrease was at 6 kg urea ha^{-1} in the sixth week, reduction of C-organic content of 13.78%, from 52.31% to 38.53% (Table 2).

Giving various dosages of urea up to 10 kg ha^{-1} for sugarcane litter for 6 weeks was not effective in reducing trash C-organic significantly. Therefore, more urea is likely required by Cinta Manis District and for longer time before application. In some studies involving longer periods (1 year or more) the sugarcane trash may reach up to 80% decomposition with various amount of urea applied in the field (De Oliveira et al., 2002). This is because the initial sugarcane litter material has high C-organic content and the presence of external influences such as rainfall occurring at the location can affect the urea content given to the litter material. When decomposition of organic matter occurs, the activity of microorganisms produces carbon so that the C-organic content increases (Jannah, 2003).

Table 2. Average organic carbon content of sugarcane litter

Urea dosage (kg ha^{-1})	The average C-organic litter (%) at week			
	0	2	4	6
0	52.11	49.69	47.07	42.25
2	50.93	53.33	45.86	45.86
4	51.32	50.60	44.44	46.68
6	52.31	49.69	46.27	38.53
8	54.47	49.89	48.10	39.75
10	52.60	49.49	47.70	41.58

When the organic material is burned, the decomposition will stop and the C-organic content will slowly drop. Decreased levels of C-organic can be seen in Figure 3. The litter organic carbon content can show the process of decomposition rate, Figure 3 shows the delta values of the initial conditions of the study that affect the litter conditions at the 2, 4 and 6 week. In the graph shows the speed of the decomposition rate of sugarcane litter where a decrease in C-organic. The lower organic carbon content in the litter, the faster the decomposition process will be because the carbon in the litter will be used by microorganisms as an energy source. This is supported by the previous research (Mirwan, 2015), which concluded that the levels of C-organic in all carbon content treatments contained in the material undergo carbon degradation during the decomposition process. C-organic is an indicator of the decomposition process in composting and maturity of compost. C-organic is carbon used as an energy source for micro-organisms to arrange cells by releasing CO_2 and other materials.

Nitrogen is an element needed by litter material for decomposition. This component is used by microorganisms as energy and it can multiply so that it can overhaul litter organic material and reduce the rate of decomposition of sugarcane litter material. The level of nitrogen in this study was not steady in value (decreased and increased until 6 week). The average value of N-total sugarcane litter can be seen in Table 3. The average values that experienced a decrease and an increase were allegedly due to the application of urea to litter material and the nature of urea that was easily lost and leached. Giving urea to the total N-content of sugarcane litter showed no significant effect, but based on the analysis using the Split Plot design, the main plot which was the time from the first week to the sixth week experienced a significant effect.

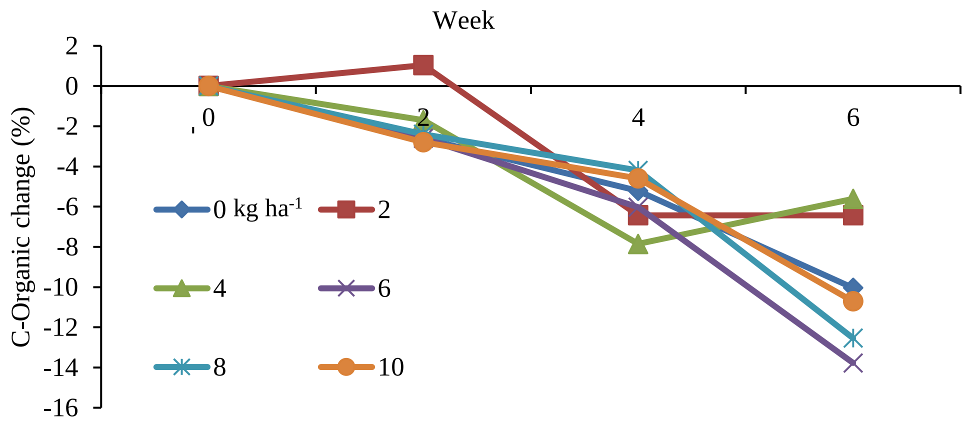

Figure 3. Two-weekly measurement of organic carbon change in sugarcane litter after urea application

Based on the average value of N-total litter in Table 3, the initial content had an overall N-total of each treatment of 0.93% at the beginning of the study and then it would affect the total N-content in the following week. The highest change in 10 kg ha^{-1} treatment increased the total N-content from 0.94% to 1.12%. The fluctuation or both increase and decrease in the total N-litter content is summarized in Figure 5. For comparison, previous researchers (Wijayanti and Prasetya, 2018) used up to 6 kg urea ha^{-1} to increase nitrogen by 15% with the addition of 4 kg ha^{-1} after 4.5 months, as compared with the control.

Table 3. Average nitrogen content of sugarcane litter

Urea dosage (kg ha^{-1})	The average nitrogen in litter (%) at week			
	0	2	4	6
0	0.89	0.95	0.91	0.89
2	0.93	0.79	0.92	1.04
4	0.85	0.88	0.73	0.94
6	1.06	1.04	0.78	0.82
8	0.93	1.03	0.82	0.95
10	0.94	0.78	0.84	1.12

The addition of urea may increase or somewhat decrease the total N-content of litter (Figure 4). In the second week, the total N-urea content decreased and increased not in concomitant pattern, with increasing urea dosage. The highest increase was in 6 kg ha^{-1} treatment and the lowest increase was in 10 kg ha^{-1} treatment. In the fourth week, the average N-total content decreased in each treatment, while in the sixth week, the content experienced a significant increase after 10 kg ha^{-1} treatment, reaching 1.12%, but decreased after 6 kg ha^{-1} treatment. This is presumably due to rainfall that occurred at the study site, which affected the total N-litter content.

The decrease in total nitrogen of litter is thought to occur due to the release of nitrogen into the air in the form of ammonia while the increase in total N content of litter is due to microorganisms that change litter and will produce nitrogen. This is supported by a research, which confirmed that increased levels are caused by the death of organisms found in the litter, which is thought to be the cause of rising nitrogen levels (Gultom, 2009). Another factor that can cause nitrogen levels to rise is the impurities of the organism. Nitrates will remain in the body of bacteria and will be released if the bacteria die. At the end of the decomposition process, microorganisms die so that the nutrient elements that are widely used by microorganisms, such as the N elements in some microorganisms that, are reedged into nutrients. From this reaction, it is obvious that the C content will decrease while the N content will remain the same, so that the C/N ratio after composting will decrease (Rosmarkam and Yuwono, 2002).

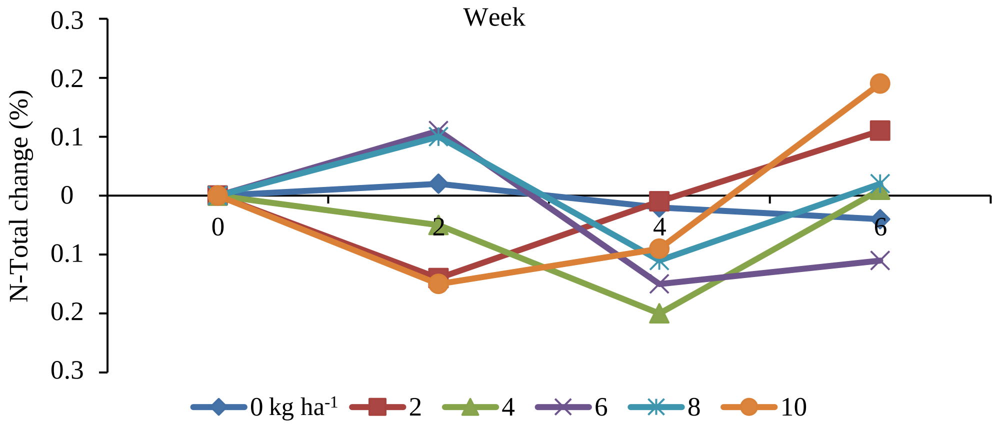

Figure 4. Two-weekly measurement of total nitrogen in sugarcane litter after urea application

Change in C/N ratio of sugarcane litter

Giving urea to C/N content of sugarcane litter ratio showed results that did not significantly affect both the treatment and the main plot, which was the time. Based on the average value of the C/N litter ratio around 58, the results of C/N ratio are considered very large for sugarcane litter decomposition. This is presumably because the

C/N ratio is influenced by the litter raw material content, which has relatively high C/N content, and external factor such as rainfall, which will affect the C-organic content and N-total of sugarcane litter after urea treatment. The average N-total amount of sugarcane litter can be seen in Table 4. The highest decrease in 10 kg ha^{-1} treatment in the sixth week was able to reduce the C/N ratio to 37.02 or decrease by 21.

Table 4. Average C/N ratio value of sugarcane litter

Urea dosage (kg ha^{-1})	The average C/N ratio litter at week			
	0	2	4	6
0	58.04	51.76	52.71	47.97
2	54.33	49.63	50.80	43.22
4	63.05	57.00	57.71	49.29
6	55.12	49.06	55.56	47.00
8	61.15	48.39	57.10	46.28
10	56.31	59.70	54.03	37.02

Giving various dosages of urea up to 10 kg ha^{-1} to sugarcane litter for six weeks can reduce the C/N ratio in general. However, it has not been effective in reducing the C/N litter ratio significantly to add nutrients to the soil. This is because the initial sugarcane litter material has a high C/N ratio, but can reduce the C/N ratio, and the presence of external influences such as rainfall that occurs at the site can affect the urea content given to the litter material. According to Yuwono (2008), low quality organic matter causes the nutrient release process to run slowly and requires a relatively long time.

Figure 5 demonstrates that the urea application affects the C/N ratio. At the second week, the C/N content of the average ratio decreased, with the highest decrease occurring in 8 kg ha^{-1} treatment to 48.39. At the fourth week, C/N overall litter ratio decreased, with the highest decrease to 50.80 taking place in 2 kg ha^{-1} treatment. Meanwhile, in the sixth week, the content experienced a significant decrease, reaching 37, at 10 kg ha^{-1}. For comparison, Wijayanti and Prasetya (2018) used up to 6 kg urea ha^{-1} and this decreased C/N by 10.94%, with the addition of 4 kg ha^{-1} after 4.5 months.

The C/N ratio is an important factor in composting process and decomposition rate because decomposing organisms use carbon as an energy source and nitrogen as a source of protein. Decrease in C/N ratio occurs during composting due to the use of carbon as an energy source and is lost in the form of CO_2, while nitrogen is used by microbes for protein synthesis and the formation of body cells so that the carbon content decreases more and higher than nitrogen content, and then the C/N ratio becomes lower.

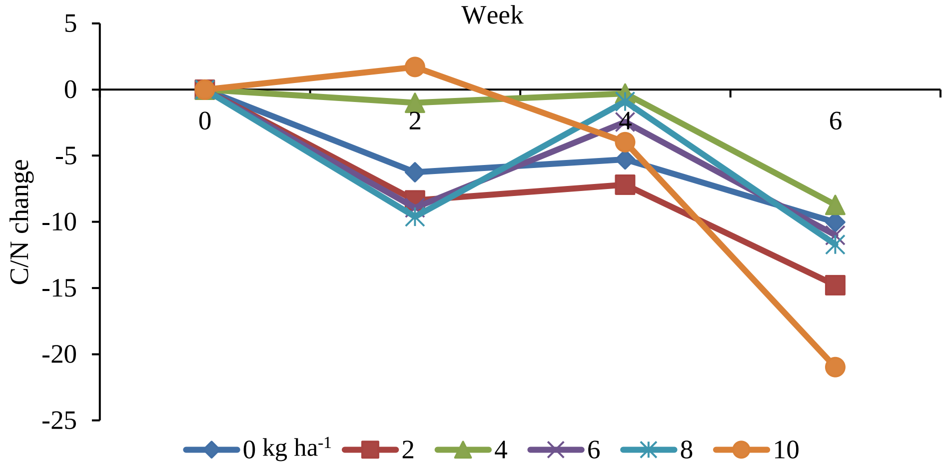

Figure 5. Net changes in C/N ratio after 6 weeks of decomposition of sugarcane litter

Soil chemical changes

Table 5 shows the average soil chemical content for pH, C-organic, N-total and C/N soil ratio. From the calculation of ANCOVA test, it was found that applying urea with different dosages showed a highly significant effect on soil pH at the study site. Decomposed sugarcane trash may induce soil pH and other nutrients (Meier and Thorburn, 2016; Dietrich et al., 2017). However, ANCOVA has shown insignificant effect of urea application on soil organic carbon, in which organic carbon increased 0.27% with 2 kg ha^{-1}. This is most probably due to the different C-organic content in each plot and a high carbon content difficult to decompose.

The dynamic of soil organic matter is strongly affected by soil moisture (Moyano et al., 2013) and sugarcane trash degradation is proportional to the initial amount of trash left on the soil surface (Dietrich et al., 2017). The authors (Thorburn et al., 2012) found that changes in the concentration of both soil C content and plant nutrients were highly site-specific and not in proportion to the period that residues were retained: for example, soil C (0-250 mm) decreased by 0.9 g kg^{-1} and 0.5 g kg^{-1} at sites where residues had been retained for 1 and 17 years, respectively, but increased by 2.0 g kg^{-1} at a site with residues retained for 6 years. Total nitrogen in soil significantly decreased after 6 weeks. A previous research (Gava et al., 2005) found that the tendency for a lower accumulation of N-urea in the sugarcane plant, in the soil surface covered with sugarcane residue, was compensated by the assimilation of N from trash mineralization. Nitrogen derived from cane trash was more available to plants in the second half of the ratoon cycle. The preceding studies (Thorburn et al., 2005; Meier and Thorburn, 2016) found that after 24 years of trash blanketing, there was a potential to reduce N fertilizer rates for crops roughly < 20 kg ha^{-1} while maintaining 95% of maximum yields.

Table 5. The average value of soil chemical content

Urea dosage (kg ha^{-1})	pH		C-organic		N-total		C/N ratio	
	x	y	x	y	x	y	x	y
0	4.94	4.75	3.64	3.16	0.21	0.15	17.04	20.54
2	4.78	4.83	3.40	3.67	0.23	0.14	14.34	20.51
4	4.68	4.82	4.01	3.92	0.20	0.15	22.90	26.53
6	4.56	4.75	3.53	3.67	0.23	0.15	15.76	24.08
8	4.82	4.81	3.62	3.60	0.20	0.15	17.81	23.09
10	5.02	4.83	3.53	3.59	0.22	0.13	15.58	26.46
Ancova	**		ns		*		ns	

Note: ** = highly significantly different; * = significantly different; ns = not significantly different

The C/N ratio of urea addition presents no significant effect at the study site. However, the overall soil C/N ratio has increased. This shows that the application of urea in sugarcane litter in the form of organic matter within 6 weeks increases because the nitrogen content in the soil and C-organic decreases, where the comparison between C and N affects the process of mineralization and immobilization. As commonly adopted (Djuarnani et al., 2005), the principle of composting is to reduce the value of the C/N ratio of organic matter to the same as the C/N ratio of soil.

CONCLUSIONS

Based on the results of research that has been done, it can be concluded that the administration of urea to sugarcane litter can affect the rate of decomposition and can reduce the C/N ratio. The largest litter decomposition with urea dosage of 10 kg ha^{-1} in 6 weeks can reduce C/N ratio by 20, followed by an increase in N total with the highest in 10 kg ha^{-1} by 0.18% and the highest C-organic reduction in 6 kg ha^{-1} by 13.78%. However, it is still an open question to determine an optimum level of urea application. In contrast to common method using litter bag and measure decrease in biomass weight, this current work focused on the changes in organic carbon and total nitrogen.

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