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Residual Effect of Ammonium Sulfate Substitution on Soil Properties and Productivity of Plant and Ratoon Cane

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Abstract: Overuse of the Ammonium Sulfate (AS) fertilizer in the long-term sugarcane cultivation has a negative impact on the soil properties which in turn can decrease soil and crop productivity. The study to describe the residual effect of AS substitute fertilizers on soil physico-chemical properties and cane productivity compared with AS fertilizer, was conducted at up-land in East Java during two cycles of the sugarcane growth (plant cane and ratoon cane). There were ten treatments which were tested consisting of three treatments using AS fertilizer, six treatments using the AS substitute fertilizer, and one control (without the use of the fertilizers). The measured variables were soil bulk density, total N, SO_4^{2-} content, soil pH, and yield variables. The use of the AS fertilizer substitute decreased the soil bulk density and increased the total N, SO_4^{2-} content, and soil pH at the post-harvest of plant and ratoon cane. It confirmed a better condition in the soil with the AS fertilizer substitute rather than the AS fertilizer by itself. The residual effect of the AS fertilizer substitute on the soil properties at the post-harvest of plant cane significantly provided a positive impact on cane and sugar yield at the ratoon cane. The soil SO_4^{2-} and total soil N content were the most important soil properties that influenced cane and sugar yield of ratoon cane. It suggests that the use of the AS fertilizer substitute is recommended on sugarcane cultivation for minimizing adverse residual effect and maintaining the soil quality.

Keywords: residual effect, soil properties, plant and ratoon cane

1. Introduction

Sugarcane is one of the major plantation crops in Indonesia and raw material of sugar mill. The total area of Indonesia sugarcane plantation in 2010 covered 434,257 ha. The average sugarcane productivity is 60-70 ton ha^{-1} and the total sugar production is 2.7 million tons. It has decreased by 20-30% compared to several years before which was 80-90 ton ha^{-1} (Directorate General of Estate of Indonesia, 2011). There are many factors which causes the decrease in sugarcane productivity such as climate change and declining in soil fertility as an impact of conventional soil management. Conventionally, the sugarcane cultivation in Indonesia used chemical fertilizers with a high dose, sub-soil tillage, burning of harvest residue, and land clearing. Thus, the long-term impacts of the conventional sugarcane cultivation system will be followed by a decline in soil health characterized by the rapid decline in soil organic matter content, soil pH, and increasing soil bulk density that can accelerate the decline in soil productivity (Haynes & Hamilton, 1999; Hairiah *et al*., 2003).

Ammonium Sulfate (AS) fertilizer is a common fertilizer used in sugarcane cultivation. Application of the AS fertilizer has been proven to increase the yield of sugarcane until the optimum dose.

However, many cane growers in Malang, East Java applied N fertilizer in excess of recommended rates by 1-2 ton AS fertilizer ha^{-1}. As the result, the demand for AS fertilizer during the season of sugarcane planting increased, this caused limited availability of the fertilizer in the markets. It impacted increase in the price of the fertilizer. It contributed increase in the cost of sugarcane production and decrease in the profitability of sugarcane farming. In addition, long term overuse of the fertilizer can have a negative impact on the soil properties. Efforts in substitution of AS fertilizer as a source of Nitrogen (N) nutrient has been studied by several researchers using urea fertilizer (Vallis *et al.,* 1996; Ismail & Simoen*,* 1999, Ammonium Nitrate fertilizer (Muchovej & Newman, 2004), filter-cake of sugar mill (Ismail & Simoen*,* 1999; Nasir & Qureshi*,* 1999; Singh *et al.,* 2007a), liquid fertilizer (Ismail & Simoen, 1999), and a combination of chemical fertilizer and organic fertilizer (Bokhtiar & Sakurai, 2007). However, the substitutions have just replaced N nutrient in AS fertilizer but not for Sulfur (S) nutrient contained in the AS fertilizer Sulfur. S nutrient plays an important role for sugarcane growth and quality. Application of sulphur up to 80 kg ha^{-1} to the crop from both the sources increased the cane yield significantly. The cane yield increased from 3.7 to 13.47 t ha^{-1} and 5.03 to 13.32 t ha^{-1} due to application of elemental sulphur and fertisulf, respectively over the control (Singh *et al*., 2007a). Viator *et al.* (2002) recorded that application of gypsum as one of S source and compost can increase Ca and S leaf concentration. However, residual effect of gypsum and compost application on soil properties and yield of ratoon cane has not been widely studied.

Soil chemical changes under sugarcane show that soil acidification is important in most soils under sugarcane. The major cause of soil acidification is the use of N fertilizers containing or producing NH_4^+ such as Ammonium Sulfate (AS) (Hartemink, 1998a). All ammoniacal N fertilizers release protons when NH_4^+ is oxidized to NO_3 by nitrifying microorganisms. Mineralization of organic matter can contribute to soil acidity by the oxidation of N and S to HNO_3 and H_2SO_4 in a similar manner (Summer, 1997). Avoiding strong soil acidification might be a better option than the use of lime to correct the high-acidity input. In addition, long-term use of chemical fertilizer can increase the soil bulk density and decline soil organic matter (Hartemink, 1998b). Since organic matter declined in most studies, it may have contributed to the increase in the soil bulk density and the soil acidity. Thus, alternative fertilizer is needed to substitute the role of AS fertilizer in sugarcane cultivation. It can reduce the negative impact of the overuse of AS fertilizer on soil quality. This study is aimed to describe the residual effect of AS substitute fertilizers on soil physico-chemical properties and crop productivity compared with AS fertilizer. The hypothesis is that the application of AS fertilizer substitute has a better effect on soil physico-chemical properties and its residual effect which further enhance the sugarcane productivity in the first ratoon as compared with AS fertilizer.

2. Materials and Methods

2.1 Location and Time Research

The field experiment was conducted on an Inceptisol soil at the dry-land of local farmers in Tegalweru village, Sub-district Dau, Malang, East Java with (07°56.638 S, 112°34.913 E and 650 m above sea level). The soil of the experimental site was loam and consisted of: 20 % clay, 49% silt, and 31 % sand. The soil had a bulk density of 1.23 g cm^{-3}. The soil was low in organic carbon (1.03 %), with pH 6.4, low in total N (0.14%), medium in phosphorus available (32.37 mg kg^{-1}), low K-available (0.13 me/100 g soil). This study was a field experiment conducted during seven months growth of sugarcane for two periods of planting. The first was plant cane (PC) and secondly was the ratoon cane (RC). This research was conducted from March 2010 to September 2011.

2.2 The Treatments and Experimental Design

This experiment used randomized block designs with three replications. There were ten treatments which were tested consisting of three treatments using AS fertilizer with a dose of 500 kg ha^{-1} (T1), 700 kg ha^{-1} (T2), and 900 kg ha^{-1} (T3), three treatments using the AS substitute fertilizer I and three treatments using the AS substitute fertilizer II. Each treatment had the equal nutrient doses of AS and one control (without the use of the fertilizers). The details of the treatments are given in Table 1 (Nurhidayati *et al.,* 2011).

Table 1. The kinds of treatments in this study

Treatments	Dose of N (kg ha^{-1})	Dose of S (kg ha^{-1})	Amount of AS (kg ha^{-1})	Amount of Urea (kg ha^{-1})	Amount of Bio-compost (kg ha^{-1})	Amount of Gypsum (kg ha^{-1})
T0	-	-	-	-	-	-
T1	100	120	500	-	-	-
T2	140	168	700	-	-	-
T3	180	216	900	-	-	-
T4	100	120	-	223	-	522
T5	140	168	-	312	-	730
T6	180	216	-	400	-	938
T7	100	120	-	110	1950	522
T8	140	168	-	155	2750	730
T9	180	216	-	200	3550	938

Note: Determination of the dose of S is based on the N and S content of AS fertilizer by 20% and 24%. The S content of Gypsum by 19 %, the N content of urea by 45%, and the N content of bio-compost by 2.57%.

2.3 The Ground Preparation for Sugarcane Planting

Soil tillage for ground preparation was done manually with a hoe. Each plot had an area of 5m × 3m in which three rows of cane were planted at an inter row spacing of 1m and 0.5 m inter plant spacing. Sugarcanes cv.BL-Red with two buds and 25 cm length were sown in the rows of the planting holes had been prepared. Six tons of seedlings ha^{-1} were required for planting. The seedlings were laid flat and buried in the ground and then covered with soil in order not to shift. In addition to fertilizers for the treatments, this study also used the basic fertilizers that were Superphosphate (SP-36) with a dose of 300 kg ha^{-1} and KCl with a dose of 200 kg ha^{-1}. Bio-compost and gypsum were applied three days before planting were distributed evenly within seed beds and then mixed with the soil. SP-36 fertilizers were applied at planting time as a whole. AS and Urea fertilizer were applied in two stages. The first stage 50% of the dose was applied two weeks after planting. The second stage 50% of the dose was applied one month after application of the first stage. KCl was given at age one month after planting as a whole. The fertilizers were applied in a hole at a distance of 10 cm from the seedlings. The similar methods were applied for the ratoon cane (subsequent plant) after harvesting plant cane (the first cane).

2.4 Soil Sampling and Analysis

The soil samples were collected from a depth of 0-15 cm and from all experimental plots using ring samples and disturb samples. The obtained samples were mixed and representative soil samples were taken for chemical analysis. The post-sugarcane harvest soil samples (0-15 cm) of all the treatments were also taken following the same procedures after the completion of the plant cane cycle and ratoon cane. In all, three sub samples were collected from each plot of all three replications. The subsamples in a plot were mixed thoroughly to obtain a representative sample for chemical analysis. The fourth month and post-harvest (seventh month) soil samples were pulverized using a ceramic-mortar and sieved through a 100-mesh sieve. The processed samples from each plot were analyzed separately for total soil N by the Kjeldahl method, SO_4^{2-} content by turbidimetric method (Okalebo *et al.*, 1993). The soil pH was determined in 1:2.5 soil water suspensions. The bulk density (BD) of the soil at the beginning of the experiment, the fourth month and after plant cane harvest and ratoon harvest were measured using a method of ring samples.

2.5 Harvesting and Assessment of Sugar Yield

The sugarcanes were harvested on November 10th, 2010 for plant cane and July 20th, 2011 for ratoon cane at the age of seven months. The representative whole plants (above-ground portion) of the planted and ratoon cane were collected from three subplots in each experimental plot. Plant cane stalks were weighed thoroughly for each treatment plot. The juice was analyzed for brix (soluble solids) using a Bausch and Lomb refractometer (Bausch and Lomb, Rochester, NY). After clarifying the juice using lead-sub-acetate, the pol (juice sucrose concentration) was determined using a polarimeter. The percentage of sucrose in the juice was computed using a formula developed from sucrose tables and temperature brix correction table. The purity of cane juice was calculated as (sucrose %/brix %) x100, and the sugar yield (t ha^{-1}) was computed as [sucrose % x cane yield (t ha^{-1})]/100 (Bokhtiar & Sakurai, 2007).

2.6 Statistical Analysis

The collected data was statistically analyzed by using the analysis of variance (ANOVA) (F-Test) at level ($P \leq 0.05$) and differences in each treatment were adjudged by the least significant difference (LSD) test ($P \leq 0.05$). The multiple regression analysis was used to determine the contribution of each soil properties to sugar and cane yield using program Minitab Vers.14.12. For statistical analysis of data (charts), Microsoft Excel was used.

3. Results

3.1 Soil Physical Properties

The significant difference in soil physical properties such as soil bulk density was recorded due to substitution of AS fertilizer for the soil sampling on the post-harvest plant and ratoon cane, but didn't occur in the measurement of the fourth month (Table 2.). At the fourth month of plant cane, the soil bulk density was lower than the seventh month (post-harvest). This was caused by the effect of soil tillage at the time of planting. Furthermore, there was no tillage until the harvest of plant cane. After harvesting the plant cane, minimum tillage was done on each plot, while pruning the cane on the soil surface. Thus, at the fourth month of ratoon cane, the soil bulk density was lower than the seventh month (post-harvest of plant cane).

The plots receiving the AS fertilizer application showed an enhancement in bulk density when compared with the control plot. The soil bulk density in the plots receiving of AS fertilizer increased by 3.4% compared with the control plot. The plots receiving applications of the substitution of AS fertilizers showed a decline in bulk density on the post-harvest measurement of the ratoon cane. The soil bulk density in the plots receiving an application of a combination of urea+gypsum decreased by 0.9% as compared with the control plot, while the plots receiving applications of a combination of urea+gypsum+bio-compost decreased by 4.3%. The highest decline had occurred in the treatment using a combination of 200 kg urea+3550 kg bio-compost+938 gypsum (Table 2).

Table 2. Effect of substitution of AS fertilizer with the combination of urea, gypsum and bio-compost on the soil bulk density of plant cane and ratoon cane

Treatments	Soil Bulk Density of Plant Cane ($g\ cm^{-3}$)		Soil Bulk Density of Ratoon Cane ($g\ cm^{-3}$)	
	4^{th} month	Post-harvest	4^{th} month	Post-harvest
T0 (no fertilizer)	1.09	1.19 cd	1.15 bc	1.19 c
T1 (500 kg AS ha^{-1})	1.09	1.18 bc	1.18 c	1.19 c
T2 (700 kg AS ha^{-1})	1.07	1.18 bc	1.17 bc	1.20 c
T3 (900 kg AS ha^{-1})	1.09	1.21 d	1.18 c	1.20 c
T4 (223 kg urea+1950 kg gypsum ha^{-1})	1.08	1.17 bc	1.15 bc	1.18 bc
T5 (312 kg urea +730 kg gypsum ha^{-1})	1.08	1.19 cd	1.13 b	1.18 bc
T6 (400 kg urea + 938 kg gypsum ha^{-1})	1.09	1.17 bc	1.14 bc	1.15 ab
T7 (110 kg urea+1950 kg bio-compost + 522 kg gypsum ha^{-1})	1.08	1.16 ab	1.13 b	1.14 ab
T8 (155 kg urea+2750 kg bio-compost + 730 kg gypsum ha^{-1})	1.07	1.17 bc	1.14 bc	1.14 ab
T9 (250 kg urea+3550 kg bio-compost +938 kg gypsum ha^{-1})	1.07	1.14 a	1.08 a	1.12 a
LSD 5%	ns	0.02	0.04	0.04

Note: Means followed by the same letter in the same column are not significantly different ($P<0.05$).
ns: non-significant

3.2 Soil Chemical Properties

The significant difference in soil chemical properties such as the total soil N, SO_4^{2-} content and soil pH was recorded due to substitution of AS fertilizer for the soil samplings on both measurements in plant cane and ratoon cane. The plots receiving applications of a combination of urea+gypsum+bio-compost had more total soil N than the other plots on the post-harvest measurement of plant cane (Fig. 1A). Thus, the residual of total soil N for this treatment is higher than the other plots. Increase in the total soil N on these plots was 36.36 % as compared with the control plot. At the post-harvest ratoon cane, the N concentration of all the treatments were higher than at the post-harvest plant cane except in the plots of T7 and T8. The highest N concentration was T6 (400 kg urea + 938 kg gypsum ha^{-1}) and T9 (200 kg urea+ 3550 kg bio-compost+ 938 kg gypsum ha^{-1}).

The plot receiving the substitution of AS fertilizer gave a higher residual of total soil N than the plot using AS fertilizer. An increase in N concentration after the harvest of plant and ratoon crops revealed a positive effect of AS substitution on the subsequent sugarcane plants. The lowest total soil N was found in the control plot and the highest in the treatments using a combination of urea+gypsum+bio-compost (Fig.1B).

The plots receiving an application of a combination of urea+gypsum and urea+gypsum+bio-compost in high doses as well as the plots using AS fertilizer had more SO_4^{2-} content than the control plot. An increase in the dose of the fertilizers can increase SO_4^{2-} content in the soil. The highest soil SO_4^{2-} concentration was found in the plots using a combination of urea+ gypsum and urea+bio-compost+gypsum in high doses at post-harvest plant cane measurement. After harvesting the ratoon cane, the soil SO_4^{2-} concentration decreased because of plant nutrient uptake during the growth of the ratoon cane. The average soil SO_4^{2-} concentration in the plot using AS fertilizer at post-harvest ratoon cane was 7.48 mg kg^{-1}, in the plot using urea+gypsum was 6.23 mg kg^{-1} and in the plot using urea+bio-compost+gypsum was 10.1 mg kg^{-1}.

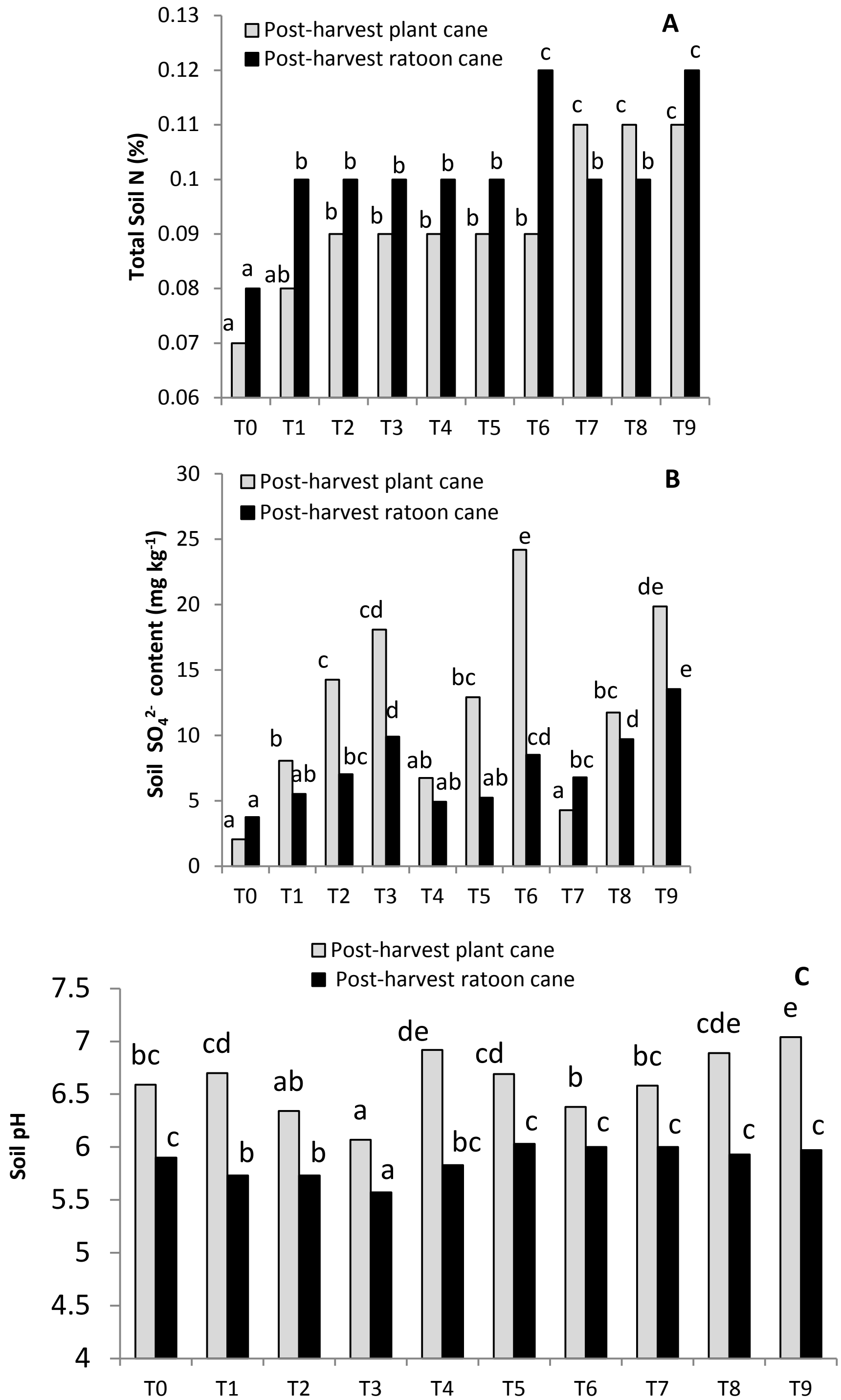

Figure 1. Comparison residual effect of AS fertilizer and its substitute using the combination of urea, gypsum and bio-compost on soil chemical properties at post-harvest plant and ratoon cane

Note: Means for the same measurement followed by the different letters in the same cane planting are significantly different ($P<0.05$)

The plots receiving applications of the AS fertilizer had a lower soil pH than the control plot, while the plot receiving the AS fertilizer substitute had a higher soil pH than the control plot on the post-harvest measurement of plant cane (Fig. 1C). Soil pHs at the plant cane were higher than the ratoon cane. It may be attributed by an increase in residual of soil SO_4^{2-} content during the growth of ratoon cane.

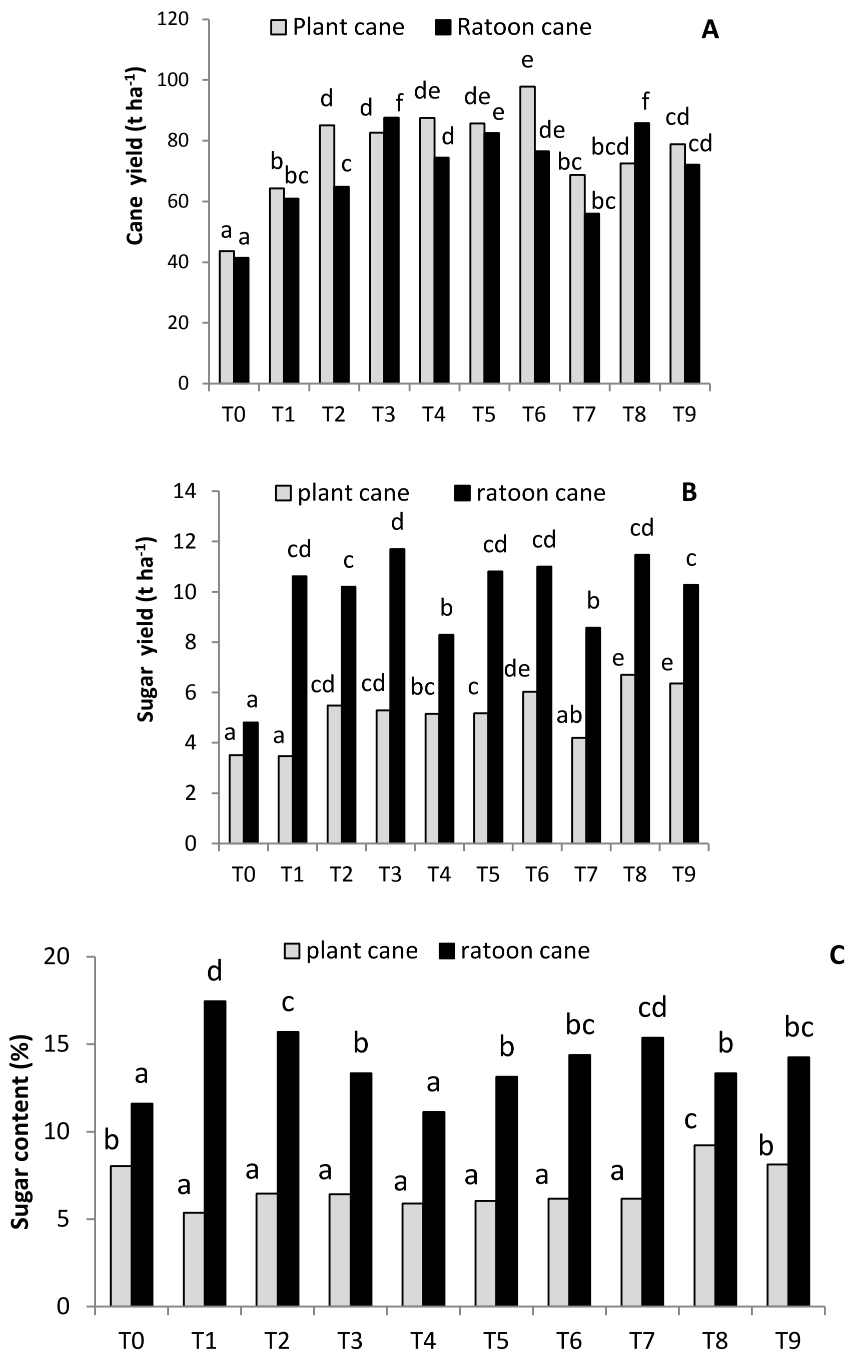

Figure 2. The effect of the substitution of AS fertilizer with the combination of urea, gypsum and bio-compost on cane and sugar yield of plant cane and ratoon cane

Note: Means for the same measurement followed by the different letter in the same cane planting are significantly different ($P<0.05$)

3.3 Sugar and Cane Yield

The sugarcane yields of plant and ratoon cane were significantly influenced by the type of tested treatments (Fig. 2A). Overall, average sugarcane yields of plant cane were higher than the ratoon cane. The sugarcane yield was greatly influenced by the soil and crop management, the climate factor, and the fertilizer application. The favorable climate can maintain the growth of ratoon cane until harvesting and increase sugar content and sugar yield. The highest yield of plant cane (97.80 t ha^{-1}) was obtained with application of 400 kg ha^{-1} urea + 938 kg ha^{-1}gypsum, whereas the highest yield of ratoon cane (87.63 and 85.84 t ha^{-1}) was obtained with AS fertilizer (900 kg ha^{-1}) and combination of 155 kg urea+ 2750 kg bio-compost+ 730 kg gypsum ha^{-1}. For plant cane, the highest sugar content (9.23%) was obtained with application of combination of 155 kg urea+ 2750 kg bio-compost+ 730 kg gypsum ha^{-1} (T8) and the highest sugar yield (6.70 and 6.36 t ha^{-1}) was obtained with application of combination of 155 kg urea+ 2750 kg bio-compost+ 730 kg gypsum ha^{-1} (T8) and 200 kg urea+ 3550 kg bio-compost+ 938 kg gypsum ha^{-1} (T9) (Fig. 2 C). For ratoon cane, the highest sugar content (17.45% and 15.38%) was obtained with 500 kg AS (T1) and combination of 110 kg urea+ 1950 kg bio-compost+ 522 kg gypsum ha^{-1} (T7) (Fig. 2 C) and the highest sugar yield was obtained with some treatments those are T1, T3, T5, T6, T8 (Fig. 2 B). The ratoon cane had higher sugar content and sugar yield than the plant cane with average increase as 105.7% and 90.1%, rspectively.

4. Discussion

4.1 The Effect of Substitution of the AS Fertilizer with the Combination of Urea, Gypsum and Bio-Compost on Soil Properties

Reduced bulk density on the plots receiving application of AS fertilizer substitute may be attributed to the application of gypsum and bio-compost which flocculate clays in the soil. This process can decrease bulk density (Havlin *et al.,* 2005; Dontsova *et al.*, 2005). The application of bio-compost enhanced the soil organic matter content. The role of soil organic matter in improving soil physical properties have been proven by some researchers to lower soil bulk density (Hati *et al.,* 2006), increase aggregation processes, water-holding capacity, hydraulic conductivity, and resistance of soil to water and wind erosion (Zebarth *et al.,*1999; Franzluebbers, 2002; Celik *et al.,* 2004)

The plot receiving the substitution of the AS fertilizer gave the higher residual of total soil N than the plot using the AS fertilizer. The bio-compost that was used in this study was organic fertilizer from by-products of sugar mill as the source of N fertilizer. It contained N-organic which was slowly released. A number of sugar mill by-products such as filter mud and boiler ash are commonly applied to the soil prior to establishment of a new sugarcane plant crop. These products contain useful quantities of essential plant nutrients, including N, P, Ca, Mg, Si, K, Cu and Zn (Barry *et al.,* 2001). Application of bio-compost increased the soil carbon content. This condition was favorable to the activity of microbes leading to mineralization and availability of nutrients to crops (Zaller & Köpke, 2004; Singh *et al.,* 2007b).

Soil pHs at the plant cane were higher than the ratoon cane. It may be attributed by the increase in residual of soil SO_4^{2-} content during the growth of ratoon cane. This suggests that the gypsum application cannot raise soil pH. The results of this study are consistent with that reported by Shamshuddin *et al.,* (2009) that the gypsum application did not significantly change the solution pH, but it gave the beneficial effect of having additional Ca and S from the dissolving gypsum, which can be taken in by the plant for healthy plant growth. However, at the post-harvest measurement, the plots receiving an application of the AS fertilizer substitute had higher soil pH than the AS fertilizer. It may be attributed by the application of urea. Urea is fertilizer with the physiological reaction of weak acid, so it doesn't lower soil pH, whereas AS is acid fertilizer containing or producing NH_4^+ such as Ammonium Sulfate (AS). All ammoniacal N fertilizers release protons which may be attributed to the decrease in soil pH (Hartemink, 1998a; Havlin *et al.,* 2005).

4.2 Relationship between Soil Properties and Sugar and Cane Yield

The results of multiple regression analysis between soil properties at the soil sampling of post-harvest plant cane with the cane yield, sugar content, and sugar yield were presented in Table 3. The multiple regression analysis showed that the cane yield was significantly influenced by soil properties at the post-harvesting of plant cane (Table 3).

Table 3. Relationships between cane yield, sugar content, and sugar yield with soil properties and their equation, regression coefficient, and P-value.

Variables	Multiple linear regression equation	Regression coefficient(R^2)	P-Value of predictor
Cane Yied (Y) Total soil N (X1) Soil SO_4^{2-} content (X2) Soil Bulk density (X3) Soil pH (X4)	Y = -1285+948 X1+1.91 X2+693 X3+36.6 X4	0.951**	Constant= 0.007 X1 = 0.003 X2 = 0.001 X3 = 0.008 X4 = 0.011
Sugarcontent (Y) Total soil N (X1) Soil SO_4^{2-} content (X2) Soil Bulk density (X3) Soil pH (X4)	Y = 121 – 5.5 X1-0.015 X2-66.8 X3-4.14 X4	0.224^{ns}	Constant = 0.309 X1 = 0.946 X2 = 0.909 X3 = 0.389 X4 = 0.347
Sugaryield (Y) Total soil N (X1) Soil SO_4^{2-} content (X2) Soil Bulk density (X3) Soil pH (X4)	Y = -63.0 + 116 X1 + 0.249 X2 + 40.7 X3 +1.81X4	0.863*	Constant = 0.201 X1 = 0.117 X2 = 0.047 X3 = 0.165 X4 = 0.492

Note: The predictor with P-value > 0.05 is not significant statistically.
ns = non significant at P level = 5%; ** =significant at P level = 1%; * = significant at P level = 5 %

The SO_4^{2-} content and soil bulk density gave the highest contribution to the cane yield of the ratoon crop. However, the soil properties did not influence the sugar content. The sugar yield was significantly influenced by the soil SO_4^{2-} content. Hartemink (1998b) reported that soil management influenced soil chemical and physical properties of sugarcane land. Application of gypsum and bio-compost can improve soil physical, chemical and biological properties (Dontsova *et al.*, 2005; Singh *et al.,* 2007b). Nasir and Qureshi (1999) reported that the residual effect of bio-compost impacted positively on sugarcane yield in first ratoon where in all bio-compost treatments applied to plant cane increased nutrient uptake in leaf tissues with significant increase in cane yield rather than the application of AS fertilizer alone. Application of gypsum can also enhance plant nutrient uptake. Gypsum reduced the loss of P and N in runoff, because of its ability to improve soil structure and retain nutrient (Favaretto *et al.,* 2006). In addition to Ca and S from gypsum can improve acid soil, soil structure and nutrient balance for plant which may attribute good and healthy plant performance and increase plant yield (Toma *et al.,* 1999; Viator *et al.,* 2002; Singh *et al.,* 2008). Singh *et al.* (2007a) reported that S nutrient played an important role for improving the quality of sugarcane yield, such as sucrose content.

Improvement of soil properties greatly determined the level of sugarcane productivity. Hairiah *et al.* (2003) reported that to maintain soil quality and productivity of sugarcane lands productivity in the tropics, the SOM content should be maintained between 2.5 - 4.0%. It required the organic matter input to be as much as 8 to 9 Mg ha^{-1} yr^{-1}. Organic matter input that is combined with N fertilizer every year on the sugarcane land in North Lampung can improve the soil organic matter status in the fourth year. Thus, the addition of organic matter can maintain the soil quality as indicators of sustainable land management under sugarcane (Haynes, 2005).

5. Conclusions

The study reveals that the substitution of AS fertilizer in the sugarcane cultivation provided a positive impact on soil properties. The applications of the AS substitute fertilizer decreased soil bulk density. It also gave an appreciable increase in the total soil N, SO_4^{2-} content and soil pH. In contrast, the application of the AS fertilizer increased the soil bulk density and decreased the soil pH, total soil N and SO_4^{2-} content. It caused the occurrence of soil compaction, a decline in nutrient availability which in turn declined the soil quality. The better residual effect of AS substitute fertilizer probably is responsible for the appreciable increase in cane and sugar yield. The soil SO_4^{2-} and total soil N content at the soil sampling of post-harvest plant cane were the most important soil properties that influenced cane and sugar yield of ratoon cane. It suggests that the use of the AS fertilizer substitute is recommended on sugarcane cultivation for maintaining the soil quality.

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