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THE LEACHING OF Ca AND Mg CATIONS ON THE APPLICATION OF CALCITE AND GYPSUM FOR SUGARCANE CULTIVATION IN CENTRAL LAMPUNG ULTISOLS

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ABSTRACT

Ultisols is one of soil types that undergoes further weathering and displays the most active cations leaching caused by precipitation. This study aimed to observe the effect of calcite application ($CaCO_3$) and gypsum (Ca_2SO_4) on valence 2 cations, such as Ca and Mg. This study was conducted in Experimental Field of Gula Putih Mataram Enterprise, Central Lampung. Split-plot design with 3 replications was used as the experimental design. The application of calcite as the main plot and the application of gypsum as the sub plot. The analysis shows that Ca analysis of leachate was relatively high than Mg if the higher rainfall happened. It could dissolve Ca from topsoil to subsoil and eventually Ca exits the soil system (solum). Meanwhile, Mg leaching by precipitation could not give clear results. It can be assumed that high rainfall would leach Ca first and then Mg, even though according to lyotropic series the bonds of Ca^{2+} is slightly stronger than Mg^{2+}. It indicates that Mg solubility by precipitation indirectly caused by high Ca solubility due to the application of calcite and gypsum. The addition of lime about 1 ton ha^{-1}, rainfall at 1264,2 mm for 166 days, caused the leaching of Ca about 596 mg and Ca uptake about 3.229 mg which is equivalent to its addition about 14.676 mg in soil. The addition of gypsum about 0,25 ton ha^{-1} will prompt the leaching about 538 mg and Mg uptake about 3.072 mg. Therefore, the application of calcite and gypsum in ultisols with high rainfall resulted in higher leaching of Ca compare to Mg.

Keywords: calcite, gypsum, base cations, sugarcane

INTRODUCTION

Indonesia is a suitable area for sugarcane growth which is supported by its climate that is very suitable for sugarcane terms of grow. It not surprising that for the last decade, the area of sugarcane is generally growing by 0,71% per year (Fitriani *et al.*, 2013). The cultivation of

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sugarcane requires loose soil type that will help aeration and root growth. Sugarcane grows well in soil which has pH of 6 – 7,5 even though it is till tolerant to pH no higher than 8,5 or no lower than 4,5. At high pH, the availability of nutrients becomes limited. On the other hand, at pH less than 5 plants will encounter Fe and Al poisoning (Indrawanto *et al.*, 2010; Augstburger *et al.*, 2000).

Ultisols is one of soil types that undergoes further weathering and displays the most active leaching by precipitation (Hardjowigeno, 1987). Nutrients leaching is a common research topic in tropical area, primarily about the displacement of cations (calcium, magnesium, and potassium) (Alcântara dan Camargo, 2005). Ultisols is characterized by deep soil solum and moderate-to-high cation exchange capacity so that this type of soil has important role in the development of dryland agriculture in Indonesia (Hardjowigeno, 1987). Ultisols can also be characterized by dominant loam type 1:1 kaolinite (Kasno et al., 2004) and macronutrient contents such as phosphorus and potassium which are often deficient (Prasetyo dan Suriadikarta, 2006). Moreover, the soil reaction ranges from acidic to very acidic and high level of saturated aluminum are common ultisols properties that often inhibit plant growth (Kasno et al., 2004; Prasetyo dan Suriadikarta, 2006; Hardjowigeno, 1987; Alloway, 1997).

Calcium (Ca) and magnesium (Mg) are two essential macronutrients that support plant growth (Hartati et al., 2012). While in ultisols, high rainfall causes both of the base cations leached, thus their availability becomes low to very low (Hardjowigeno, 1987). This low availability needs to be considered because plant growth will be disturbed if macronutrient deficiency occurs. Availability of Ca and Mg currently rely solely on the reserves in the soil (Hartati et al., 2012). Field studies are difficult to conduct due to nutrient loss through leaching depending on the application dosage and solubility of the fertilizer, application time, water conditions, root development and mainly quantification of water flux through the soil (Blum et al., 2013).

Until recently, the application of $CaCO_3$, $CaSO_4$ or $CaMg(CO_3)_2$ of the existing research sites are aimed at increasing pH and supplying soil with Ca and Mg. Therefore, it is necessary to evaluate how far the effectiveness of calcification in ultisols with high rainfall patterns. The objectives of this research were to observe the effect of lime application ($CaCO_3$) and gypsum (Ca_2SO_4) to the dynamics of Ca and Mg elements dissolved in leachate. Then the pattern of Ca and Mg leaching in ultisols would be discovered, which later could be used as consideration in the calcification effort in acidic soil for cultivation.

METHODOLOGY

The research was conducted in Experimental Field of Gula Putih Mataram Enterprise, Central Lampung District in November 2013 to May 2014. The materials used are ultisols soil,

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sugarcane seedlings of XC-09, lime ($CaCO_3$) with 92,5% purity, gypsum (CaO content by 30,29% and S content by 22,01%), fertilizers such as ZA, urea, TSP, and KCl. Tools used are plastic drums for sugarcane planting, scale, ruler, tape ruler, oven, pH meter, EC meter, spectrophotometer, and AAS.

The soil came from Experimental Research Field of Gula Putih Mataram Enterprise which previously had been brushing by harrows to cut and chop the stumps. The soil was rejuvenated and re-harrowed twice. Drums with 56 cm and 60 cm height were filled with soil with 40 cm height. Then the soil was compressed with a pressure of 400 N. Mixture of soil-gypsum-lime was added until it reached 20 cm height. Therefore, there were 120 kg of soil in a drum. All treatments received the same type of fertilizers which were ZA, urea, TSP, and KCl at about 5; 14,2; 5 and 12 gram per drum.

Split-plot experimental design with 3 replications was used for data processing. The lime application ($L=CaCO_3$) as the main plot with 4 levels, which are the dosage of lime starting from 0, 1, 2, and 3 tons ha^{-1}. While the application of gypsum ($G=CaSO_4.2H_2O$) as the sub plot with 4 levels, which are the dosage of gypsum starting from 0; 0,25; 0,5 and 1 ton ha^{-1}. The parameters observed were dissolved Ca and Mg contents in leachate. In this case, no additional irrigation water is added. Overall, the water leached only comes from rainfall. The measurements of leachate were conducted 47 times over a period of 166 days, with various observation time ranges from every day to once in 20 days depending on the rainfall event. The leaching water was taken in the morning after rainfall events. And the rainfall was recorded using ombrometer.

The calculation of Ca amount input is the amount of Ca contained in lime ($CaCO_3$) or gypsum ($CaSO_4$) with purity 92.5% and 90%, respectively. Meanwhile, leached Ca calculation is the amount of Ca content in water leaching, multiplied by the volume of water leaching at each observation. Ca uptake by sugarcane is obtained from the percentage of nutrients (%) contained in plants multiplied by the total dry weight of the plants (grams), with the assumption that the nutrient content of Ca in each plant tissue is the same.

Determining the effect of lime and gypsum application on various observed parameters can be done by analyzing the observed data using analysis of variance. If there is any significant difference in the treatments, the test will be followed by Duncan's Multiple Range Test at 5%.

ANALYSIS RESULTS

1. Characteristics of Ultisols in Central Lampung

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Ultisols is used in this research which has characteristic of a very bright, very leached, gray-to-yellowish-gray surface layer over a relatively heavy textured horizontal accumulation of red or yellow with a clump structure, less stable aggregates, and low permeability. Table 1 shows the initial condition of leachate studies, indicating the availability of base cations such as Ca, Mg, and Na which were in low to very low level. The low base cations triggered soil acidity to increase (Cahn et al., 1993). Meanwhile, macro nutrients such as N and K were low to very low, while the level of available P was very high. The low cation exchange capacity and nutrient content in soil proves that the soil has undergone further leaching and even it has reached the most advanced level in its development

2. Rainfall Characteristics in Research Region

In this study, the water source used to fulfil the plant requirements was only from rainfall. It really determined the process of characteristic change of soil, mainly chemical properties. High rainfall would help higher water leaching. In addition, the availability of water might change soil chemical conditions, including soil pH, nutrient availability, increase nutrient ionization so that it was absorbed by the plant through active or passive absorption.

The study took place from October to April, which was the time of rainy season in Indonesia. Based on the observations, rainfall in the study area was 1264.2 mm and rainy days of 100 days during planting on October 23rd 2013 until completing the observation on April 10th 2014. Thus, the average rainfall at that time was 12.6 mm per rain day. Therefore, there is an increase of 350 ml of rainfall added on one drum. Due to the high rainfall during the period, it was possible that the leaching process would take place in a fast period with a high amount.

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Table 1. Characteristics of Ultisols in Central Lampung

Parameters	Units	Depth (cm)		Criteria	Method
		0-20	20-40		
pH H_2O	-	5,00	4,63	M	H_2O rasio 1:2,5
pH KCl	-	4,44	4,11	SM	KCl rasio 1:2,5
Al_{dd} (me%)	cmol kg^{-1}	0,39	0,65	S	KCl 1 N
H_{dd} (me%)	cmol kg^{-1}	0,59	0,65	S	KCl 1 N
C-Org (%)	%	13,0	7,9	R – SR	Walkey and Black
N total (%)	%	1,0	0,8	R	Kjedahl
C/N Ratio	-	12,57	10,57	S – R	-
K	cmol kg^{-1}	0,17	0,06	R – SR	Ammonium Asetat pH 7
Na	cmol kg^{-1}	0,08	0,07	SR	Ammonium Asetat pH 7
Ca	cmol kg^{-1}	1,24	0,69	SR	Ammonium Asetat pH 7
Mg	cmol kg^{-1}	0,55	0,28	R – SR	Ammonium Asetat pH 7
CEC	cmol kg^{-1}	24,67	21,12	S	Ammonium Asetat pH 7
Available Fe	mg kg^{-1}	370,31	260,27	ST	Morgan wolf
Available Mn	mg kg^{-1}	3,20	1,97	R – S	Morgan wolf
Available Cu	mg kg^{-1}	0,14	0,11	R	Morgan wolf
Available Zn	mg kg^{-1}	0,19	0,10	R	Morgan wolf
S total	%	0,72	0,56	-	Pengabuan basah
Available P	mg kg^{-1}	87,64	22,19	ST	Bray I

Description :
ST : very high
T : high
S : moderate
R : low
SR : very low
SM : very acidic
M : acidic

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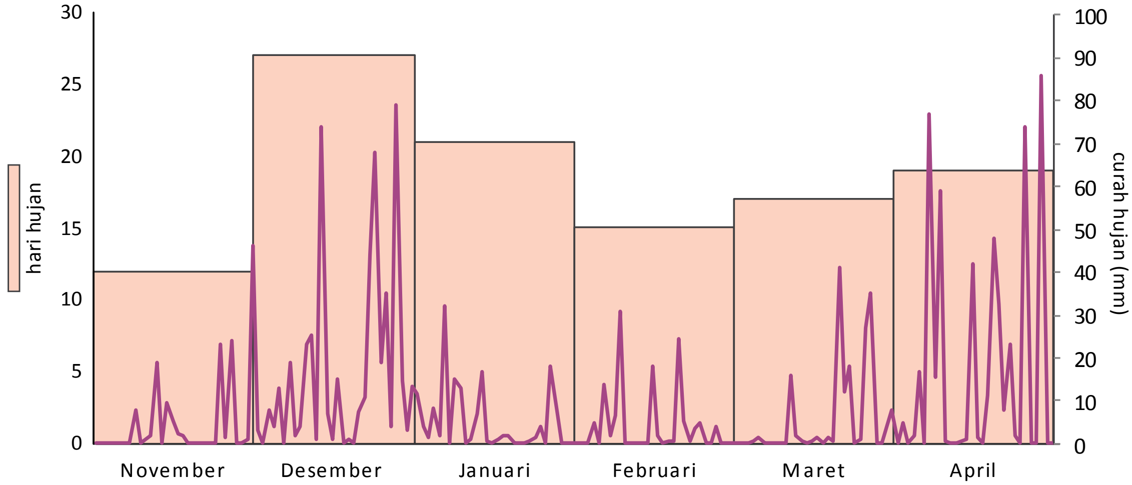

Figure 1. Rainfall and rainy days in research location

3. Soil Acidity (pH)

Acidity or soil pH is one of the factors affecting growth and production of sugarcane since it affects nutrient availability. Soil reactions that are otherwise resistant to pH indicate the acidity or concentration of H^+ ions and OH^- ions in the soil. Table 2 and 3 display there are no interaction between lime and gypsum dosage of soil acidity in both observing layer of 0-20 cm and 20-40 cm depth. Each factor, either lime or gypsum, also do not show any significant differences. This suggests that lime and gypsum applications have not been able to increase soil pH in sugarcane cultivation.

Table 2. The effect of lime and gypsum application to soil H2O pH within 0-20 cm depth

Lime (ton ha^{-1})	Gypsum (ton ha^{-1})				Average
	0	0,25	0,5	1	
0	5,72	5,77	5,82	5,69	5,75 a
1	5,94	5,77	5,90	5,90	5,88 a
2	6,05	6,06	6,11	6,17	6,10 a
3	5,98	5,82	5,90	5,98	5,92 a
Average	5,92 p	5,85 p	5,93 p	5,93 p	-

Description : The average number followed by the same letter in row or column shows no significant difference based on DMRT at 5%

\- : no significant interaction.

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Table 3. The effect of lime and gypsum application to soil H_2O pH within 20-40 cm depth

Lime (ton ha^{-1})	Gypsum (ton ha^{-1})				Average
	0	0,25	0,5	1	
0	5,38	5,24	5,11	5,27	5,25 a
1	5,44	5,64	5,40	5,29	5,44 a
2	5,75	5,50	5,51	5,85	5,65 a
3	5,42	5,41	5,94	5,52	5,57 a
Average	5,50 p	5,45 p	5,49 p	5,48 p	-

Description : The average number followed by the same letter in row or column shows no significant difference based on DMRT at 5%

- : no significant interaction.

4. Ca content

Calcium, along with magnesium and sulfur, is macronutrients which are needed by plants in large quantities. The dynamics of Ca in water leaching shows that there was increasing of leached Ca on December 12th 2013 or the 47th day due to increased rainfall. While early January to March there was relatively low rainfall, leached Ca was also low. The application of lime about 3 ton ha^{-1} caused higher leached Ca (Figure 2), while in the application of lime about 1 and 2 ton ha^{-1} leaching value was not much different. The same thing occurred in the application of gypsum, while the application about 0.25 and 0.5 ton ha^{-1} shows that leached Ca has the same value, while with the increase of gypsum application to 1 ton ha^{-1}, the leaching increases.

Table 4 shows that the number of leaching is relatively very small compared to the applied Ca. The application of lime had Ca content higher than gypsum, while leached calcium was not much different which means the percentage of leached Ca on lime was much lower than in gypsum. Ca uptake by sugarcane is obtained from the percentage of plant nutrients multiplied by the plant dry weight. Along with the application of lime or gypsum that adds Ca content in the soil, it also affects the Ca uptake of plant. In the application of 1 ton ha^{-1} shows the uptake of Ca to be 3,229 mg, while with the addition of 3 tons ha^{-1} shows the uptake to be 3,704 mg. Similarly, the addition of gypsum of 0.25 and 1 ton ha-1 showed the Ca uptake of 3,072 and 3,312 mg,

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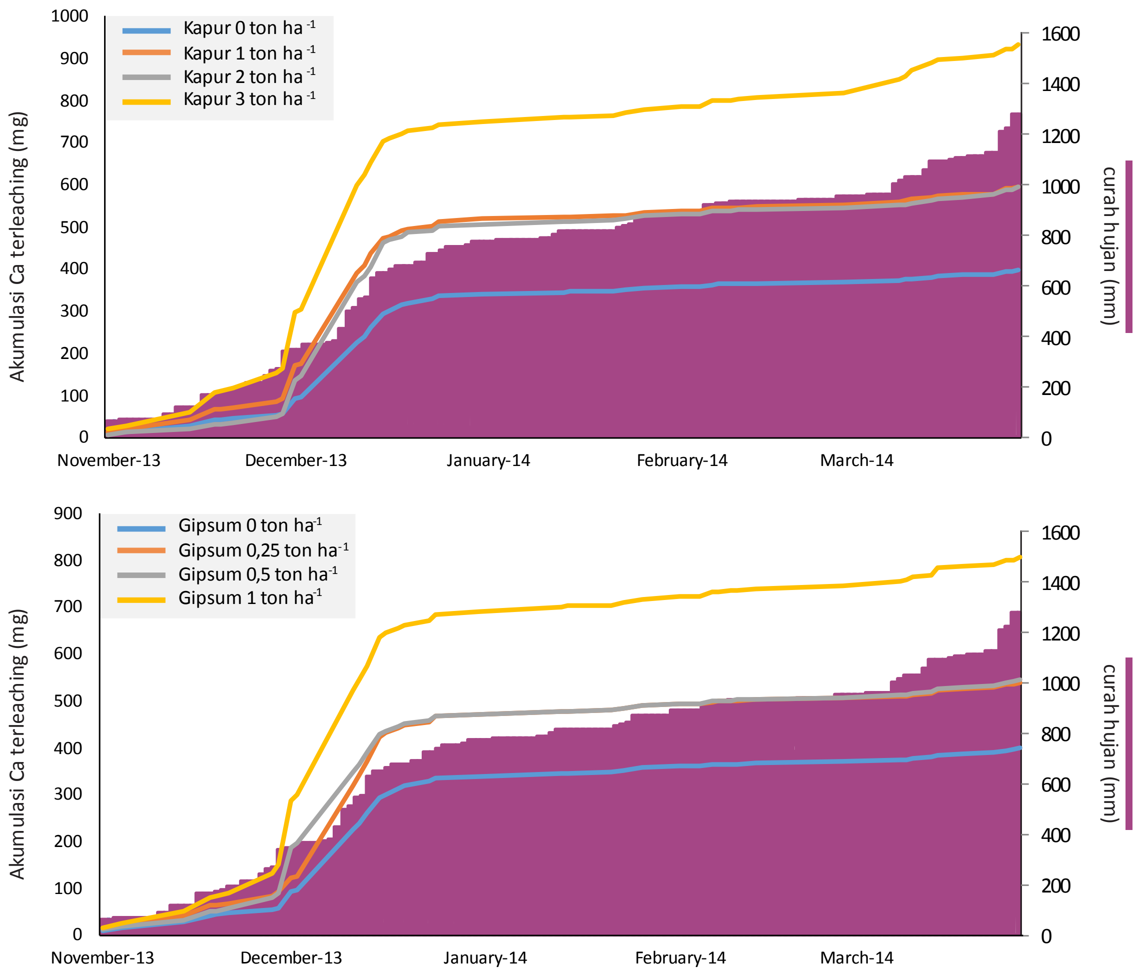

Figure 2. The dynamics of Ca content of leachate on lime and gypsum treatments and its relation to rainfall

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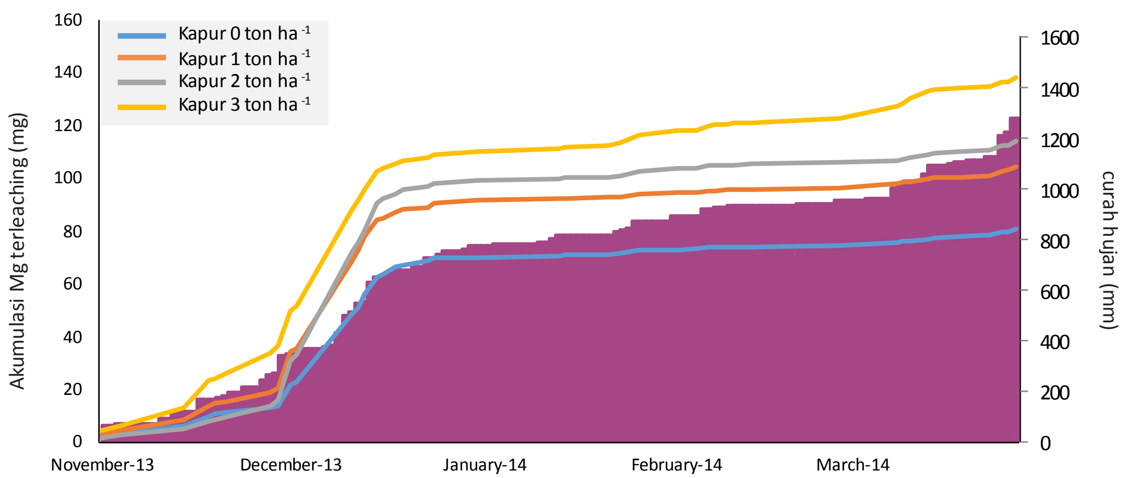
Table 4. Calculation of calcium input to leached and absorbed calcium

Treatment	Calcium input (mg)	Leached calcium (mg)	% leached calcium input	Calcium absorbed by sugarcane (mg)	Stored calcium (mg)
Lime	18.500	596	3,22	3.229	14.676
	37.000	597	1,61	3.244	33.159
	55.500	935	1,68	3.704	50.861
Gypsum	2.433	538	22,13	3.072	-1.178
	4.866	545	11,20	3.114	1.206
	9.732	807	8,29	3.312	5.613

5. Mg Content

The absence of magnesium input from lime or gypsum causes the existing magnesium to be derived only from the initial condition. The results might be different if the type of ameliorant used was dolomite which formula is $CaMg(CO_3)_2$. The dynamics of leaching on Mg showed similar results to Ca, such as Mg would be leached in high rainfall. In mid-December as rainfall increases, it appears that leached Mg also increases. While in low rainfall it also appears that leached Mg also decreases.



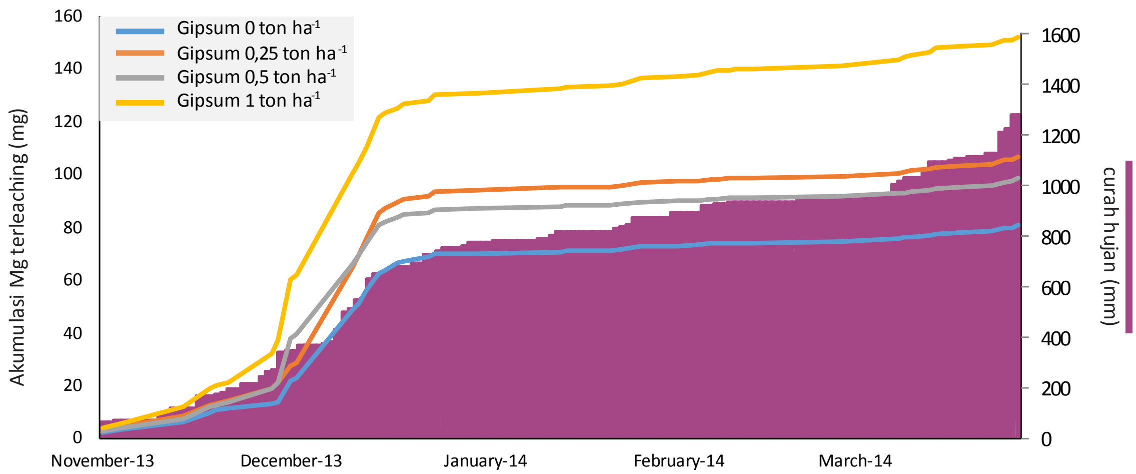


Figure 4. The dynamics of Mg content of leachate on lime and gypsum treatments and its relation to rainfall

DISCUSSIONS

The condition of pH required by plants is pH which is corresponding to the anatomical and physiological of the plant itself. Therefore, the change in pH is needed when necessary in order to meet the plant's needs. This is due to soil pH determines the availability of nutrients needed by plants. Soil pH in layer 0-20 cm depth ranging from 5,77-6,17 which is moderately acidic and in 20-40 cm depth ranging from 5,11-5,94 which is in acidic-moderately acidic. Based on analysis of variance shows in Table 2 and 3, there are no significant effect of lime and gypsum application on soil pH. The initial pH H_2O of soil at 5,0 is already relatively high. Therefore, the application of lime and gypsum to increase pH value is relatively ineffective. In addition, the existence of buffering capacity defines as the soil ability to retain pH changes may be the cause of no significant effects of applied treatments.

Leaching is the release of dissolved ions and the movement of water in the soil profile that removes the ions (Ghiberto et al., 2009). The increase of Ca leaching on the 47th day is possible because after application of lime and gypsum, it takes a few time until water can dissolve Ca and exits the solum. The application of lime and gypsum mixed on topsoil (0-20 cm) enables it to happen. The overlay of the Ca dynamics of leachate with rainfall also adds the support. On the 47th day, there was an increasing trend of rainfall accompanied by an increase in leaching water containing Ca (Figure 3). Pretty heavy rain is able to dissolve the Ca from the top layer (0-20 cm) to the lower layer (20-40 cm) to exit from the solum. While the next rainfall event was not too high, the leaching was only possible only in the upper layer to the bottom layer. The higher

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application of lime and gypsum given tends to increase leached Ca. The same is also applied to leached Mg.

Based on the analysis of Ca input, leached and absorbed Ca by plants, the application of lime of 1 ton ha^{-1} shows the results of leaching of 596 mg, nutrient uptake of 3,229 mg, which results in additional Ca of 14,676 mg in soil. This is in accordance with Ghiberto et al., 2009 which conveys that leaching of nutrients in sugarcane is relatively lower than the nutrients given by calcification. Noted that the measured sugarcanes were 6 month-old crops and rainfall was 1264.2 mm. The presence of Ca uptake in plants was much greater than leaching due to Ca is an essential macro nutrient needed by plants in large quantities. Assuming leaching of 596 mg and nutrient uptake for 6 months was 3,229 mg, the application of lime about 1 ton ha^{-1} would last for 2.4 years. While on the application of gypsum about 0.25 ton ha^{-1}, it shows a negative value which means the application of gypsum 0.25 ton ha^{-1} has not been balanced against Ca uptake by sugarcane and high leaching by rainfall.

Both Ca and Mg are valence 2 cations and based on the lyotropic series, they are relatively more difficult to be exchanged and leached than K^+, Na^+, H^+, $NH4^+$ and so on. Therefore, the loss of Ca about 530-940 mg and Mg about 80-150 mg in the soil is relatively normal. Based on the lyotropic series, although both are valence 2+, Mg^{2+} element is slightly more easily exchanged and leached than Ca^{2+}. However, in this study it is obtained that Ca leaching value is higher than Mg^{2+}. It is possible that saturation of Ca in the soil will affect nutrient dissolution. The presence of Ca in large quantities in the soil will cause Ca more easily leach out of the ground than Mg. Ghiberto et al., 2015 reported that in soil solution when compared to molarity, Ca^{2+} element is the dominant cation, followed by K^+ and Mg^{2+}.

CONCLUSIONS

The presence of the dynamics of leached calcium and magnesium elements from solum can be explained by magnesium bonds and the concentration of Ca in the soil due to the addition of lime and gypsum. First, the high rainfall would tend to leach nutrients with high concentration, such as Ca. High Ca content was the result of lime and gypsum which further leads to an increase in Ca concentration in the soil, either in the complex form or in the soil solution. The Ca domination causes rain water to easily leach Ca in the soil solution, although according to lyotropic series Ca^{2+} is stronger than Mg^{2+}. Based on Figure 3 and 5, precipitation causes leaching of Ca first and then followed by Mg. Therefore, indirectly Mg solubility by rainfall is influenced by Ca solubility in concentrated conditions. Second, the nutrients in the soil are in two locations, namely the soil solution and the complex form. Since Ca and Mg both are valence 2 cations, it would require more ions than the bonds of valence 1, such as K^+, Na^+ or $NH4^+$ ions.

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Therefore, Ca and Mg are not easily bound in the complex form. This resulted in both of these nutrients sufficiently in the soil solution that is easy to leach. And with the high rainfall, Ca and Mg become more easily leached.

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