Journal of Agricultural Science; Vol. 8, No. 12; 2016
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

The Influence of Lime and Nitrogen Fertilizer on Soil Acidity, Growth and Nitrogen Uptake of Corn in Total Reclaimed Potential Acid Sulphate Soil

Yuli Lestari[1], Azwar Maas[2], Benito Heru Purwanto[2] & Sri Nuryani Hidayah Utami[2]

[1] Indonesian Swampland Agriculture Research Institute (ISARI), Banjarbaru, Indonesia

[2] Agriculture Faculty, Gadjah Mada University, Yogyakarta, Indonesia

Correspondence: Yuli Lestari, Indonesian Swampland Agriculture Research Institute (ISARI), Banjarbaru, Indonesia. Tel: 62-(0511)-477-2534. E-mail: yulibalittra70@yahoo.com

Received: September 18, 2016 Accepted: October 25, 2016 Online Published: November 15, 2016

doi:10.5539/jas.v8n12p197 URL: http://dx.doi.org/10.5539/jas.v8n12p197

The research is financed by Indonesian Agency for Agricultural Research and Development (IAARD).

Abstract

This study aims to determine the effect of lime and nitrogen fertilizer on soil acidities characters, growth and nitrogen uptake of corn in total reclaimed of potential acid sulphate soil. A pot experiment with a completely randomized design arranged in factorial with three replications was conducted in the Greenhouse of Indonesian Swampland Agricultural Research Institute (ISARI) from August 2014 to December 2015. The first factor was the rate of lime as dolomite: (i) 25 $t \cdot ha^{-1}$, and (ii) 37.5 $t \cdot ha^{-1}$. The second factor was the type of nitrogen fertilizer: (a) control (without N), (b) nitrogen 115 $kg \cdot ha^{-1}$, (c) chicken manure 6 $t \cdot ha^{-1}$ (the total N content is 1.98%) and (d) nitrogen 57.5 $kg \cdot ha^{-1}$ + 3 $t \cdot ha^{-1}$ chicken manure. Urea (N content is 39.76%) was used for fertilization. The observed variables were the soil acidities properties (pH, Electrical conductivity/EC, available-H, available-Al) before, after total reclamation, and at the maximum vegetative stage of corn, plant growth and uptake of shoot nitrogen. The results showed that the process of consecutively aeration-leaching of the potential acid sulphate soils able to increase the soil pH, declining the EC value, as well as availabe bases, available-H, available-Al and the content of pyrite. The application of dolomite increased soil pH, EC, and available-H, while available-Al decreased, its effect was more pronounced in higher rate. Application of dolomite 25 $t \cdot ha^{-1}$ and 37.5 $t \cdot ha^{-1}$ respectively increased soil pH from 3.29 to 4.36 and 4.87, EC from 0.70 $mS \cdot cm^{-1}$ to 1.51 $mS \cdot cm^{-1}$, available-H from 1.30 $cmol(+) \cdot kg^{-1}$ to 2.68 $cmol(+) \cdot kg^{-1}$ and 1.44 $cmol(+) \cdot kg^{-1}$ and decreased available-Al from 14.04 $cmol(+) \cdot kg^{-1}$ to 4.71 $cmol(+) \cdot kg^{-1}$ and 2.66 $cmol(+) \cdot kg^{-1}$. However, these rates was not able to neutralize the existing acidity due to the acidity still being produced out of remaining pyrite which was still in active stages. It was showed increasing pH soil followed by EC. The interaction between the application of dolomite and nitrogen fertilizer is significantly influenced plant height and shoot N uptake. The highest plant height and shoot N uptake were 112 cm and 267.69 $mg \cdot plant^{-1}$ respectively, were obtained in application dolomite 25 $t \cdot ha^{-1}$ combined with nitrogen 57.5 $kg \cdot ha^{-1}$ plus chicken manure 3 $t \cdot ha^{-1}$. The highest of averages shoot and root dry weight was 20.97 g and 6.40 g respectively which were obtained in the application of nitrogen 57.5 $kg \cdot ha^{-1}$ + chicken manure 3 $t \cdot ha^{-1}$.

Keywords: potential acid sulphate soil, total reclamation, dolomite and N fertilizer

1. Introduction

Potential acid sulphate soils are soils containing iron sulphide mainly pyrite (FeS_2) that stable in anaerobic condition within the pH tending to be neutral. There are two approaches to utilize the potential acid sulfate soil, namely (1) limiting the oxidation of pyrite and prevent acidity by maintaining groundwater levels (suitable for rice), (2) maximizing the oxidation of pyrite by drying and wetting intensively and discharging oxidation products through leaching (Arunin et al., 2009).

The potential acid sulphate soil can be used for upland crops after a "total reclamation" is applied, means that maximizing the aeration and leach out of its oxidation product untill the remaining pyrie not active anymore. Usually if the pyrite content reaching a value less then 0.75% and the EC is less than 0.5 $mS \cdot cm^{-1}$ (Maas, 2003).

During the acitve pyrite oxidation, produces high concentration of ferrous ions and sulfuric acid (H_2SO_4) which resulted in extreme acidity of soil and water. The strong acid then release aluminium and other acid soluble-metals by cation exchange or oxide dissolution (Kawahigashi et al., 2008). Therefore, an important next step in the process of reclamation through oxidation-leaching is to decrease soil acidity and toxic elements through leaching of pyrite oxidation products. However leaching to discharge acidity and other toxic compounds can cause the water to become acidic, nutrient leaching and an increase of Al saturation. Thus after the reclamation process, it is necessary to neutralize the residual acid left in the soil.

According to Anda et al. (2009), the process of leaching as a part of the management of the backswamp results in the leaching of nutrient N. The effluent in the secondary canals in Dadahup (Central Kalimantan, Indonesia) containing NH_4^+ 0.08-0.14 me·L^{-1}, and NO_3^- 0.02-0.03 me·L^{-1}, while in the secondary canals in Palingkau (Central Kalimantan, Indonesia) it containes NH_4^+ 0.06-0.27 me·L^{-1}, and NO_3^{-1} 0.01 me·L^{-1}. This shows that the process of oxidation-leaching results in decreased fertility of acid sulphate soils, so that to improve them additional N fertilizer is needed.

As already mentioned above, the oxidation-leaching also result in decreased soil pH, increased concentration of Al^{3+} and Al saturation due to leach of bases. The soil pH before the reclamation was 4.5-6.5 and 3.5-4.5 after reclamation (Anda et al., 2009). Meanwhile the influence of Al toxicity in plants is to inhibit the division and elongation of the meristem cells which in turn lowers the growth of plant roots (Panda et al., 2003; Mora et al., 2006). In addition, Al toxicity triggers an increase in the reactive oxygen species (ROS), causing oxidative stress that can damage the roots and chloroplast, decreasing normal functioning of photosynthetic parameters. Al-toxicity may also increase or inhibit antioxidant activities, which are responsible to scavenge ROS. As result of the negative effects of toxic Al, root metabolic processes, such as water and nutrient absorption, are disturbed with a concomitant decrease in calcium (Ca) uptake (Merino-Gergichevich et al., 2010). Therefore, to reduce the activity of Al in acid sulphate soils reclaimed by oxidation leaching it is necessary increase the soil pH.

A common management practice to increase the pH and lowers aluminum toxicity in acid sulphate soils is by application of lime. Liming often used are calcite ($CaCO_3$), dolomite ($CaCO_3 \cdot MgCO_3$) or a mixture of both. According to Pankova et al. (2009), liming on acid soils in addition to lowering the activity of Al^{3+}, increases the availability of P and also increases the rate of mineralization of N from organic materials.

Post reclamation of acidic environments such as low pH and high soil Al saturation resulted in supply constraints and N absorption. Therefore require the addition of lime and N fertilizer is required. Source N in potential acid sulphate soil is usually in the form of organic and inorganic. Therefore we need a study of the utilization of these two sources combined with liming to improve the availability and uptake of nutrients. The aim of this study was to investigate the influence of lime and nitrogen fertilizer on the character of soil acidity of the potential acid sulphate soils after oxidation-leaching, uptake of N as well as the growth of corn.

2. Materials and Methods

The experiment was conducted at the Greenhouse of Indonesian Swampland Agricultural Research Institute (ISARI) from August 2014 to December 2015. The potential acid sulphate soil used in the study came from Jelapat, Barito Kuala, South Kalimantan on 3º14′16.1″S, 114º31′02″E, taken at a depth of 35-65 cm and classified as Typic Sulfaquent. Based on prior research, the soil in this site have high pyrite content. Potential acid sulphate soils used for growing media for upland crop were previously aerated and leached consequtively. The process of aeration-leaching was by air drying of potential acid sulphate soils, washing the oxidation product repeatedly. The chemical properties of potential acid sulphate soils before and after the air dry are presented in Table 1.

In the process of oxidation-leaching, the soil and sieved air dried soil with rice husk was mixed in the 2:100 based on the dry weight (0.2:10 kg). Once well blended grain it was put into sacks put for drying-leaching by immersion in a large basin of local well water containing as much as 25 l for 3 days. Then it was drained and dried for 7 days. The drying and leaching process was conducted for 6 months.

Table 1. Chemical properties of acid sulfate soils before oxidation-leaching

	Acid sulfate soil before air dry (sulphidic material)	Acid sulfate soil after air dry*
pH H_2O	4.81	2.97
EC ($mS \cdot cm^{-1}$)	0.99	8.62
N-total (%)	0.18	0.20
Available-K ($cmol(+) \cdot kg^{-1}$)	0.23	1.02
Available-P ($mg.kg^{-1}$)	10.89	20.42
Available-K ($cmol(+) \cdot kg^{-1}$)	3.19	3.09
Available-Ca ($cmol(+) \cdot kg^{-1}$)	0.75	1.87
Available-Mg ($cmol(+) \cdot kg^{-1}$)	8.84	9.03
Available-H ($cmol(+) \cdot kg^{-1}$)	4.39	7.60
Available-Al ($cmol(+) \cdot kg^{-1}$)	11.38	25.30
Pyrite content (%)	4.39	2.64

Note. * acid sulfate soil used for next research.

The pot experiment to find the kind of nitrogen fertilizer to improve the fertility of potential acid sulphate soils after oxidation-leaching used the indicators of corn crop of the Sukmaraga variety. The treatment was arranged in a factorial completely randomized design with three replications. The first factor was the rate of dolomite lime: (a) 25 $t \cdot ha^{-1}$ and (2) 37.5 $t \cdot ha^{-1}$. The second factor was the type of fertilizer: (a) Control (without N), (b) Nitrogen 115 $kg \cdot ha^{-1}$, (c) 6 $t \cdot ha^{-1}$ chicken manure^{-1} and (d) Nitrogen 57.5 $kg \cdot ha^{-1}$ + 3 $t \cdot ha^{-1}$ chicken manure. Overall the number with three replications of treatments was 2 × 4 × 3 = 24 units.

The acid sulphate soils after reclaimed by oxidation-leaching were given of lime and incubated for 2 weeks. Then as many as 3 Sukmaraga corn seeds sown in pots containing 3 kg of air dry. Once the plants grew well (±7 day after sown), thinning was done, leaving one of the best plants in each pot. Basic fertilizers such as TSP 150 $kg \cdot ha^{-1}$ was applied at planting, whereas KCl 140 $kg \cdot ha^{-1}$ was applied when the plant was 1 week and 4 weeks old. Maintenance included watering until field capacity conditions using local well water. Plants were maintained until the maximum vegetative phase, harvested at 8 weeks after sown (WAS). Characteristics of lime, urea, TSP, KCl and chicken manure are presented in Table 2.

Table 2. Characteristics of chemical dolomite lime, urea, TSP, KCl and chiken manure

Chemical properties	Ameliorative materials/fertilizer				
	Dolomit	Urea	KCl	TSP	Chiken manure
Ca (%)	22.98				2.86
CaO (%)	32.17				
N (%)		39.76			1.98
K_2O (%)			43.94		-
P_2O_5				33.61	
P (%)					1.19
K (%)					1.89
Mg (%)	8.69				0.56
Na (%)					0.17
C-organic (%)					36.79

Observations of acid sulphate soils were made at the time before the air dry, after air dry and after leaching with local well water including; pH (H_2O) 1:2.5, EC (1:2.5), cations such as Na^+, Ca^{2+}, Mg^{2+}, K^+, and Al^{3+} as well as the levels of pyrite. Observations on plant growth at maximum vegetative phase (end of the experiment) in terms of height, shoot dry weight, root dry weight, uptake of N. Observation on soil chemical properties after harvest (maximum vegetative phase) which comprised pH H_2O (1:2.5), EC (1:2.5), available-H and available-Al.

Analysis of pH used a glass electrode pH meter HORIBA Model 9625 and analysis of EC used EC-meter glass electrode WTW Cond Model 3110. Analysis of N-total by the Kjeldahl method used H_2SO_4 wet ashing and then titrated. Cations such as Na^+, Ca^{2+}, Mg^{2+} were extracted using NH_4OAc pH 7 and analyzed using AAS (Atomic Absorption Spectrometry) GBC Model 933 plus. Analysis of H^+ and Al^{3+} by titration used KCl 1 M extracter. Analysis of the levels of pyrite oxidation method used H_2O_2 and was measured using Spectrophotometer Model Spectronic 20 (λ = 494 nm).

The data obtained in this experiment were analyzed statistically using SAS software Portable 9.1.3. Analysis of varian was done to determine the treatment difference. The duncan multiple range test (DMRT) was used to compare treatment means at $P < 0.01$ or $P < 0.05$.

3. Results

Chemical properties of acid sulphate soils after oxidation-leaching for 6 months or as much as 16 times of drying-wetting and then leaching by 10 times are shown in Table 3. Table 3 shows that the soil reaction (pH) increased while the EC decreased. Concentration of bases such as Ca^{2+}, Mg^{2+}, K^+ and Na^+, acid cation H^+ and Al^{3+} and nutrient such as total-N, available-P, decrease due to oxidation-leaching. The oxidation-leaching proses caused the pyrite content decrease from 2.63% to 0.93%.

Table 3. Changes of chemical properties of potential acid sulfate soil after oxidation leaching

Chemical properties	Before leaching	After leaching
pH H_2O	2.97	3.29
Electrical conductivity (mS·cm^{-1})	8.62	0.78
N-total (%)	0.20	0.24
Available P (ppm)	20.42	6.91
Available K (cmol(+)·kg^{-1})	1.02	0.07
Available Na (cmol(+)·kg^{-1})	3.09	0.42
Available Ca (cmol(+)·kg^{-1})	1.87	0.70
Available Mg (cmol(+)·kg^{-1})	9.03	0.47
Available Al (cmol(+)·kg^{-1})	25.30	14.04
Available H (cmol(+)·kg^{-1})	7.60	1.30
Pyrite content (%)	2.64	0.93

Interaction between liming and nitrogen fertilization did not affect the soil pH. Only liming as the sole factor that significantly affected in soil pH (Table 4). Application of dolomite 25 t·ha^{-1} and 37.5 t·ha^{-1} respectively increased soil pH from 3.29 to 4.36 and 4.87.

Table 4. The effect of dolomite lime and nitrogen fertilizer on the pH of potential acid sulphate soils after oxidation-leaching at the maximum vegetative stage of corn

Rate of dolomite	The type of N fertilizer				Average**
	Control (Without N)	Nitrogen 115 kg·ha^{-1}	Chicken manure 6 t·ha^{-1}	Nitrogen 57.5 kg·ha^{-1} + chicken manure 3 t·ha^{-1}	
25 t·ha^{-1}	4.28	4.61	4.24	4.33	4.36 B
37.5 t·ha^{-1}	4.96	4.90	5.06	4.57	4.87 A
Average	4.62 P	4.76 P	4.65 P	4.45 P	(-)

Note. Means with the the different capital letter within column differ significantly by DMRT ($p < 0.01$).

The effects of dolomite lime, nitrogen fertilizers and their interaction on soil EC were not significantly different (Table 5). On average the EC of potential acid sulphate soils that had undergone oxidation leaching from application of dolomite lime and nitrogen fertilizers was 1.51 mS·cm^{-1}.

Table 5. The effect of dolomite lime and nitrogen fertilizer on the EC of potential acid sulphate soils after oxidation-leaching at the maximum vegetative stage of corn

Rate of dolomite	The type of N fertilizer				Average**
	Control (Without N)	Nitrogen 115 kg·ha^{-1}	Chicken manure 6 t·ha^{-1}	Nitrogen 57.5 kg·ha^{-1} + chicken manure 3 t·ha^{-1}	
25 t·ha^{-1}	1.60	1.46	1.89	1.54	1.62
37.5 t·ha^{-1}	1.30	0.87	1.12	1.26	1.42
Average	1.45	1.18	1.50	1.40	(-)

Note. Means with the the different capital letter within column differ significantly by Duncan test ($p < 0.01$).

The interaction between the application of dolomite and N fertilizer did not significantly affect Al^{3+} and H^+ in the soil. Al^{3+} and H^+ in the soil was affected by a single treatment of dolomite. Application of dolomite 37.5 t·ha^{-1} caused Al^{3+} and H^+ to be lower than 25 t·ha^{-1} (Tables 6 and 7).

Table 6. The effect of dolomite lime and fertilizer application on the available-H (cmol·kg^{-1}) of potential acid sulphate soils after oxidation-leaching at the maximum vegetative stage of corn (8 WAS)

Rate of Dolomite	The type of nitrogen fertilizer				Average*
	Control (Without N)	Nitrogen 115 kg·ha^{-1}	Chicken manure 6 t·ha^{-1}	Nitrogen 57.5 kg·ha^{-1} + chicken manure 3 t·ha^{-1}	
25 t·ha^{-1}	3.23	1.40	3.13	2.93	2.68 A
37.5 t·ha^{-1}	1.20	1.47	1.30	1.80	1.44 B
Average	2.22 P	1.43 P	2.22 P	2.37 P	(-)

Note. Means with the the different capital letter within column differ significantly by DMRT ($p < 0.05$).

Table 7. The effect of dolomite lime and N fertilizer on the available-Al (cmol·kg^{-1}) in the potential acid sulphate soil after oxidation-leaching at the maximum vegetative stage of corn (8 WAS)

Rate of Dolomit	The type of nitrogen fertilizer				Average*
	Control (Without N)	Nitrogen 115 kg·ha^{-1}	Chicken manure 6 t·ha^{-1}	Nitrogen 57.5 kg·ha^{-1} + chicken manure 3 t·ha^{-1}	
25 t·ha^{-1}	5.00	3.47	5.00	5.37	4.71 A
37.5 t·ha^{-1}	1.93	3.17	2.80	2.73	2.66 B
Average	3.46 P	3.32 P	3.90 P	4.05 P	(-)

Note. Means with the the different capital letter within column differ significantly by Duncan DMRT ($p < 0.05$).

The interaction between application of dolomite lime and N fertilizer significantly affected plant height 8 WAS (Table 8). The height of plants applied with N fertilizer was higher than the control (without N) at the rate of dolomite 25 t·ha^{-1} and 37.5 t·ha^{-1} except the combination treatment 37.5 t·ha^{-1} dolomite and nitrogen 115 kg·ha^{-1} there was not significant difference from the control.

Table 8. The effect of dolomite lime and N fertilizer to plant height (cm) of corn at the maximum vegetative stage (8 WAS) on the potential acid sulphate soils after oxidation leaching

Rate of Dolomit	The types of nitrogen fertilizer				Average
	Control (Without N)	Nitrogen 115 kg·ha^{-1}	Chicken manure 6 t·ha^{-1}	Nitrogen 57.5 kg·ha^{-1} + chicken manure 3 t·ha^{-1}	
25 t·ha^{-1}	60.50 c	97.67 a	105.37 a	112.50 a	94.01
37.5 t·ha^{-1}	71.67 bc	79.33 b	102.50 a	108.83 a	90.58
Average	66.08	88.50	103.94	110.67	(+)

Note. Means with the the different capital letter within row or column differ significantly by DMRT ($p < 0.01$).

Shoot and root dry weight of corn is not influenced by the interaction between the application of dolomite and N fertilizer. Only N fertilizer as a single factor had significant effect on shoot dry weight and root of corn (Tables 8 and 9). Tables 8 and 9 show that the average dry weight of the shoot and roots of corn applied with N fertilizer was significantly different from the control (without N). The combination of nitrogen fertilizers 57.5 kg·ha^{-1} + 3 t·ha^{-1} chicken manure gives highest shoot dry weight, *i.e.* 20.97 g was not significantly different compared to chicken manure 6 t.ha^{-1}, but significantly different from the application of 115 kg·ha^{-1} nitrogen. The highest root dry weight was obtained in the combination treatment of nitrogen fertilizer 57.5 kg·ha^{-1} + 3 t·ha^{-1} manure followed by manure 6 t·ha^{-1} then giving 115 kg·ha^{-1} nitrogen.

Tabel 9. The effect of application of dolomite lime and nitrogen fertilizer on shoot dry weight (g) of corn at maximum vegetative stage (8 WAS) on the potential acid sulphate soils after oxidation leaching

Rate of Dolomite	The type of nitrogen fertilizer				Average
	Control (Without N)	Nitrogen 115 kg·ha^{-1}	Chicken manure 6 t·ha^{-1}	Nitrogen 57.5 kg·ha^{-1} + chicken manure 3 t·ha^{-1}	
25 t·ha^{-1}	2.70	10.87	20.67	23.20	14.36 A
37.5 t·ha^{-1}	3.63	8.80	18.93	18.73	12.95 A
Average**	3.17 R	9.83 Q	19.80 P	20.97 P	(-)

Note. Means with the different capital letter within row differ significantly by DMRT ($p < 0.01$).

Tabel 10. The effect of application of dolomite lime and nitrogen fertilizer on root dry weight (g) of corn at maximum vegetative stage (8 WAS) on the potential acid sulphate soils after oxidation leaching

Rate of Dolomit	The type of nitrogen fertilizer				Average
	Control (Without N)	Nitrogen 115 kg·ha^{-1}	Chicken manure 6 t·ha^{-1}	Nitrogen 57.5 kg·ha^{-1} + chicken manure 3 t·ha^{-1}	
25 t·ha^{-1}	1.60	2.30	4.07	6.74	3.68 A
37.5 t·ha^{-1}	1.57	3.33	5.57	6.07	4.13 A
Average**	1.58 S	2.82 R	4.82 Q	6.40 P	(-)

Note. Means with the the different capital letter within row differ significantly by DMRT ($p < 0.01$).

N uptake of corn at 8 was significantly affected by the interaction between the application of dolomite and N fertilizer N. Table 11 shows that application of nitrogen fertilizers can increase N uptake except that the combination of lime 37.5 t·ha^{-1} and 115 kg·ha^{-1} N was not significantly different from the control (35.5 t·ha^{-1} dolomite and without N). It was due to leaching. Leaching occured because the bottom of the pot experiment was provided with a hole for good draining if there was an excess volume of watering.

Tabel 11. The effect of application of dolomite lime and fertilizer nitrogen to shoot nitrogen uptake (mg·plant^{-1}) of corn at the maximum vegetative stage (8 WAS) on the potential acid sulphate soils after oxidation leaching

Rate of Dolomit	The type of nitrogen fertilizer				Average
	Control (Without N)	Nitrogen 115 kg·ha^{-1}	Chicken manure 6 t·ha^{-1}	Nitrogen 57.5 kg·ha^{-1} + chicken manure 3 t·ha^{-1}	
25 t·ha^{-1}	34.55 d	175.39 b	234.44 a	267.69 a	177.92
37.5 t·ha^{-1}	55.33 cd	86.27 c	159.03 b	256.70 a	139.33
Average	44.94	150.83	196.74	261.99	(+)

Note. Means with the the different capital letter within row or column differ significantly by DMRT ($p < 0.01$).

4. Discussion

In this research, an increase in pH is associate with a decrease in concentration of acid cation (H^+ and Al^{3+}). According to Rosilawati et al. (2014) an increase in pH is caused by the consumption of protons (H^+) or precipitation of Al^{3+} to the $Al(OH)_3$. Because pKa of Aluminum is 5, while in the research oxidation-leaching resulted in soil pH 3.29, the increase in pH was caused by the consumption of protons. Proton consumption result in decreasing of concentration of H^+ so that soil pH increased.

The oxidation-leaching process resulted in the decrease of the EC of potential acid sulphate soils. According to Agus et al. (2008), EC was affected by salts such as NaCl, Na_2SO_4, $MgSO_4$, $NaHCO_3$, $NaCO_3$, $CaSO_4$ and $CaCO_3$. The lower the concentration of salts in the soil solution caused the lower of the electrical conductivity. Besides a decrease in the concentration of H^+ which is also resulted in decreased EC. Results of research by Blunden (2000) on the chemical status of groundwater after oxidation of pyrite showed that the lower the concentration of total SO_4^{2-}, Cl, Al^{3+}, Fe^{2+}, Ca^{2+}, Mg^{2+}, K^+ and Na^+, the lower the EC of groundwater. Therefore, the decrease in the EC of potential acid sulfate soils after oxidation-leaching in this study was due to the reduced concentration of bases such as Ca^{2+}, Mg^{2+}, K^+ and Na^+ as well as acid cation H^+ and Al^{3+}. In addition, the leaching of acid sulfate soils intended to discharge the pyrite oxidation products such as H^+, SO_4^{2-} also involved the leaching of plant nutrients such as N and P as well as bases such as K, Na, Ca and Mg.

Table 3 shows that continous oxidation-leaching decreased the pyrite content from 2.63% to 0.93%. According to Kusel (2003), pyrite is a mineral which was not stable in strongly reduce condition, and become unstable to form soluble compound in oxidation stage. The acceleration of pyrite oxidation can be carried out by lowering the soil moisture to increase aeration, continuous leaching-oxidation and repeated wet-dry conditions (Maas, 2000). In this study, decrease of 64.77% in the pyrite content was a result of the drying treatment for 7 days, followed by leaching and this process was repeated 16 times.

The highest rate of dolomite applied the greeter the pH increase. The results of an incubation experiment by Rosilawati et al. (2014) on acid sulphate soil Typic Sulfaquept shows that the application of dolomite increase the soil pH by increasing the doses applied. Similar results were also obtained by Wijanarko and Taufiq (2016), that soil pH would increase from 4.3 to 4.5 along with an increase of lime. Furthermore Rosilawati et al. (2014) pointed out that the increased pH resulting from the provision of dolomite is due to the consumption of proton (H^+). By decreasing the concentration of H^+, the pH of the soil is increased.

The EC of the acid sulphate soils after to the application of dolomite and nitrogen fertilizer was higher than before application (0.78 $mS\cdot cm^{-1}$). This shows that the pyrite content in acid sulfate soils used as a growing medium was still reactive (EC = 1.51 $mS\cdot cm^{-1}$). Application of dolomite up to 37.5 $t\cdot ha^{-1}$ increased soil pH but did not decrease EC. This suggests that the rate of lime is not able to neutralize the acidity of existing resources for the remaining pyrite oxidation was still reactive and the oxidation was still ongoing.

Application of lime up to 37.5 $t\cdot ha^{-1}$ can neutralize the H^+ and Al^{3+}, but as the remaining pyrite were still reactive, the residual lime had the role to neutralize the product of further oxidation of the remaining pyrite. The data showed pH still below 5 and EC still above 0.5 $mS\cdot cm^{-1}$.

Application of dolomite 25 $t\cdot ha^{-1}$ and 37.5 $t\cdot ha^{-1}$ decreased available-Al from 14.04 $cmol(+)\cdot kg^{-1}$ to 4.71 $cmol(+)\cdot kg^{-1}$ and 2.66 $cmol(+)\cdot kg^{-1}$ while increased soil pH from 3.29 to 4.36 and 4.87 respectively. According to Bohn et al. (2001), at pH 4-5 forms of aluminium are Al^{3+}, $Al(OH)^{2+}$ and $Al(OH)_2^+$. Therefore decreasing of available-Al is due to the amount of Al^{3+} that have convert to $Al(OH)^{2+}$ and $Al(OH)_2^+$.

Combination of inorganic (urea) and organic (chicken manure) fertilizer can improve plant growth. Vegetative growth that is reflected in plant height can be associated with the element N which is a constituent of chlorophyll. N sufficient supply results in more chlorophyll content causing a better photosynthetic activity, which in turn induce a better growth vegetative.

The application of the same N fertilizer type did not affect plant height at the application of lime with different doses but in the application of fertilizer N 115 $kg\cdot ha^{-1}$, the height of plants applied with dolomite 37.5 $t\cdot ha^{-1}$ was lower than dolomite 25 $t\cdot ha^{-1}$ application. This was presumables related to the type of N available in the soil and uptake by plants. According to Mengel and Kirby (1989), the plant will absorb the N-NO_3 at low pH and absorb NH_4^+ at pH close to neutral. Furthermore, according to Kirk (2004), N-NO_3^- as the stable species under oxic condition and decrease along with increase soil pH. Thus it can be said that the application of lime with a higher dose cause N-NO_3 not stable (change other form) so decreases and reduce the N uptake and as a result plant height is also affected.

According to Sudhakar et al. (2016) plant dry weight is most useful and reliable to measurement of plant growth. The dry weight of the plant is a mix of plant genetic and environmental factors. Environmental factors that affect plant growth are the soil reaction and the availability of plant nutrients. Control of environmental factors to achieve ideal conditions for plant growth enables growth and crop production to reach a maximum in accordance with the genetic condition. It can be concluded that the combined treatment of nitrogen 57.5 $kg\cdot ha^{-1}$ + 3 $t\cdot ha^{-1}$ chicken manure mentioned above are the most ideal conditions for plant growth compared with treatments. This is due to the use of N sources of manure and urea can be complementary. Inorganic fertilizer N can provide rapidly for vegetative growth of the plants, while the manure release nutrients slowly and reduce possible leaching of nutrients. Manure also contains other nutrients such as P, K, Ca and Mg (Table 2). Organic materials contained in manure can increase the ability to water retention (Doberman & Fairhurst, 2000) and increase the absorption capacity so the loss of nutrients from the soil is reduced. Furthermore, organic fertilizers can improve the efficiency of inorganic fertilizer, which in turn can promote plant growth (Usman et al., 2015).

N uptake in the treatment of 115 kg N·ha^{-1} and chicken manure 6 t·ha^{-1} with dolomite 37.5 t·ha^{-1} was lower than 25 t·ha^{-1}, but combination treatment of nitrogen 57.5 kg·ha^{-1} + 3 t·ha^{-1} chicken manure was not differ. It showed that application of lime high dose with 115 kg N·ha^{-1} 115 or chicken manure 6 t·ha^{-1} caused N uptake decrease but no effect at application urea and chiken manure together.

5. Conclusion

Application of dolomite can increase the pH of the soil, lower the available-H and available-Al. The highest plant growth was obtained on a combination of nitrogen 57.5 kg·ha^{-1} and chicken manure 3 t·ha^{-1} at a dose of dolomite 25 t·ha^{-1} and 37.5 t·ha^{-1}. The highest dry weight of shoot and root was obtained at application of nitrogen 57.5 kg·ha^{-1} and chicken manure 3 t·ha^{-1}.

Interaction between the application of dolomite 25 t·ha^{-1} and combination of nitrogen 57.5 kg·ha^{-1} and chicken manure 3 t·ha^{-1} resulted in the highest shoot N-uptake (267.69 mg·plant^{-1}). This is not different from the interaction between the application of dolomite 25 t·ha^{-1} and chicken manure 6 t·ha^{-1} (105.37 mg·plant) and the interaction between the application of dolomite 37.5 t·ha^{-1} and a combination of nitrogen 57.5 kg·ha^{-1} and chiken manure 3 t·ha^{-1} (108.83 mg·plant^{-1}). It was conclude that the application of lime and N fertilizer can increase N uptake as wellas corn growth and soil fertility of potential acid sulfate soil after oxidation-leaching.

6. Suggestion

In the total reclamation of potential acid sulfat soil, the oxidation process of pyrite should be carried out until it reaches the phase when the soil is no longer reactive which is marked by the low concentration of the remaining pyrite (< 0.75%) or EC(< 0.5 mS·cm^{-1}). The purpose is to ensure that the application of dolomit is more effective and efficient in neutralizing available H and available Al.

References

Agus, F., H., Subagiyo, Rahman, A., & Subiksa, I. G. M. (2008). *Properties of tsunami affected soils and the management implication*. Paper was presented at 2nd International Salinity Forum, March 31-April 3, 2008, Adelaide. Retrieved March 16, 2010, from http://www.internationalsalinity.org

Anda, M., Siswanto, A. B., & Subandiono, R. E. (2009). Properties of organic and acid sulfate soil and water of a 'reclaimed' tidal backswamp in Central Kalimantan, Indonesia. *Geoderma, 149*, 54-65. http://dx.doi.org/10.1016/j.geoderma.2008.11.021

Arunin, S., Zaidelman, F. R., Khitrov, N. B., & Pankova, Ye. I. (2009). Particular forms of Land Amelioration Development of Coastal Marshlands and Other Saline soil. In B. S. Maslov (Ed.), *Agricultural Land Improvement Ameliorant and Reclamation* (Vol. 2, pp. 289-308). EOLLS Publishers Co. Ltd., Oxford, United Kingdom.

Blunden, B, G. (2000). *Management of Acid sulfate soil by Groundwater Manipulation* (Thesis). University of Wollongong. Retrieved from http://no.uow.edu.au/these/1834

Bohn, H. L., McNeal, B. L., & O'Connor, G. A. (2001). *Soil Chemistry* (3rd ed.). John Wiley & Sons, Canada.

Doberman, A., & Fairhurst, T. (2000). *Rice Nutrient Disorder and Nutrient Management*. Potash and Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and IRRI.

Kawahigashi, M., Do, N. M., Nguyen, V. B., & Sumida, H. (2008). Effects of drying on the release of solutes from acid sulfate soils distributed in the Mekong Delta, Vietnam. *Japanese Society of Soil Science and Plant Nutrition, 54*, 495-506. http://dx.doi.org/10.1111/j.1747-0765.2008.00275x

Kirk, G. (2004). *The Biogeochemistry of Submerged Soil*. John Wiley & Sons. Ltd., New York, USA. http://dx.doi.org/10.1002/047086303x

Kusel, K. (2003). Microbial cycling of iron and sulfur in acidic coal mining lake sediments. *Water, Air and Soil Pollution, 3*, 67-90. http://dx.doi.org/10.1023/A:1022103419928

Maas, A. (2003). *Opportunities and Consequences of Swampy Land Use in the Future*. Inauguration Speech Position Professor at the Faculty of Agriculture, Gadjah Mada University, Yogyakarta, Indonesia.

Maas, A., Sutanto, R., & Purwadi, T. (2000). The effect of sea water on the pyrite oxidation and nutrient retention in acid sulphate soil. *Journal Tanah dan Lingkungan, 2*(2), 41-45.

Mengel, K., & Kirby, E. A. (1987). *Principle of Plant Nutrition* (4th ed.). International Potash Institute, Worblaufen-Bem, Switzerland.

Merino-Gergichevich, C., Alberdi, M., Ivanov, A. G., & Reyes-Diaz, M. (2010). Al^{3+}-Ca^{2+} interaction in plants growing in acid soils: Al-phytotoxicity response to calcareous amendments. *J. Soil Sci. Plant Nutr., 10*(3), 217-243. http://dx.doi.org/10.4067/SO718-95162010000100003

Mora, M. L., Alfaro, M. A., Jarvis, S. C., Demanet, R., & Cartes, P. (2006). Soil aluminium availability in Andisols of Southhern Chile and its effect on forage production and animal metabolism. *Soil Use and Management, 22*, 95-101. http://dx.doi.org/10.1111/i.1475-2743.2006.00011x

Panda, S. K., Singha, L. B., & Khan, M. H. (2003). Does aluminium phytotoxicity induce oxidative stress in greengram (*Vigna radiata*)? *Bulg. J. Plant Physiol, 29*, 77-86. Retrieved from http://www.bio21.bas.bg/ipp/gapbfiles/v-29/03-1-2-77-86.pdf

Pankova, Ye. I., Khitrov, N. B., Novikova, A. P., Koroleva, I. B., Utkaeva, V. F., Varob'eva, L. A., … Redly, M. (2009). Chemical Amelioration of Soils. In B. S. Maslov (Ed.), *Agricultural Land Improvement Ameliorant and Reclamation* (Vol. 2, pp. 144-184). EOLLS Publishers Co. Ltd., Oxford, United Kingdom.

Rosilawati, A. K., Shamsuddin, J., & Fauziah, C. I. (2014). Effects of incubating an acid sulfate soil treated with various liming materials under sumerged and moist conditions on pH, Al and Fe. *African Journal of Agricultural Researh, 9*(1), 94-112. http://dx.doi.org/10.5897/AJAR12.289

Sudhakar, P., Ladha, P., & Reddy, P. V. (2016). *Phenotyping Crop Plants for Physiological and Biochemical Trait*. BS Publication, A Unit of BSP Book Pyt Ltd., India.

Usman, M., Madu, V. U., & Alkali, G. (2015). The combined use of organic and inorganic fertilizers for improving maize crop productivity in Nigeria. *International Journal of Scientific and Research Publication, 5*(Issue 10), 1-7. Retrieved from http://www.ijsrp.org/research-paper-1015/ijsrp.p4698.pdf

Wijanarko, A., & Taufiq, A. (2016). Effect of lime application on soil property and soybean yield on tidal land. *Agrivita, 38*(1), 14-23. http://dx.doi.org/17503/agrivita.v38i.683

Copyrights