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To cite this article: M S Imanudin *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **757** 012036

Leaching Treatment of Acid Sulphate Soil and Crop Adaptation Test under Micro Scale Condition

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Abstract. Agricultural problem on acid sulphate soil is related to high concentration of iron and aluminum which can be toxic to crops. The research objective was to determine soil leaching intensity or frequency effect on decreasing iron and aluminum concentration. Results from this research information can be used to develop field strategy in order to determine time and period for land leaching. Moreover, crop adaptation toward leached soil was conducted on corn crop. Experiment was conducted in laboratory of soil physics department of soil science. Duration of leaching was set up in the 5, 10, 15 days. The pH of iron and aluminum was analyzed before treatment. Iron content was at 11.58 ppm and pH was at 3.29. The result showed that the leaching option had highly significant effect on the increasing pH and reducing iron content. The pH was increase at 3.85, 4.07, 4,26 and 4.34 respectively for 5, 10 and 15 days of leaching. It was also followed by reducing iron content of 9.29, 7.08 and 5.06 respectively for 5, 10 and 15 days of leaching. Within 15 day (two weeks duration) it was sufficient time to facilitate leaching process in the field. Climatic data showed that the rainfall was available during land preparation stage (November for first crop and March for second crop). On the other hand, the drainage facility should be developed in tertiary block to leach out the toxic element in the roots zone. This process should be done in the beginning of rainy season. Adaptation toward corn crop showed that 5 times leaching treatment was sufficient to provide good environment for crop's growth.
Keywords: Sulphate Soil; Concentration; Iron; Aluminum; pH; Content

1. Introduction

Land clearing of tidal lowland in South Sumatra had been conducted since 1960. The main objective of this effort is for developing food crop agriculture enterprise. Most of this land was classified into acid sulphate soil. Because most of this area had degraded and became unproductive land, the planting index (PI) currently was about 100 and rice production was lower with magnitude of about 3.0 ton.ha-1 [1]. Degradation on acid sulphate soil is commonly dominated by (a). Acidization process on soil and water due to phyrite oxidation and (b). Leaching of bases as an impact from acid leaching [2].

Poor drainage condition results in increasing iron (Fe2+) concentration in roots zone which is toxic to crops. Acid sulphate soil is characterized by phyrite layer existence at depth of 50-60 cm below soil surface. During dry season and uncontrolled soil watertable condition up to phyrite layer depth results in oxidation process for long time period and subsequently produce land acidity. This condition causes unstable mineral grids which in turn increasing heavy metals precipitation such as Al, Mn, Zn and Cu [3].

In addition, soil having acid reaction results in low nutrients content especially phophorous element due to fixation by aluminum and iron. Low soil fertility condition in turn cause low rice production on acid sulphate soil at Air Sugihan area. According to [4], low production of land at Air Sugihan because it has shallow layer of acid sulphate in the range of 50 to 70 cm and the drawdown of soil watertable at dry season up to 100 cm below soil surface had results in phyrite layer oxidation. Proper management for acid sulphate soil will still produce good rice production. The study by [5] at acid sulphate soil that had no phyrite oxidation (undegraded) was capable to produce 4 to 5 ton.ha-1 of rice.

The degraded acid sulphate soil can be improved by leaching treatment. Land leaching is capable to decrease toxic elements concentration such as $Fe2+$, $SO4$ 2-, $H+$ and soil acidity [6]. High concentration of $Fe2+$ is harmful for crops growth. Rice production had decrease about 30 to 100% depending on toxicity level and soil fertility [7]. The study conducted by [8] showed that the field leaching treatment combined with soil tillage was capable to increase rice production from about 2 ton.ha-1 (without leaching treatment) to 3.5 ton.ha-1 (with leaching treatment).

Based on the above discussion, land leaching for acid sulphate soil is an effective method to improve soil fertility status. The problem is when and how often land leaching should be done because data of leaching time and frequency is currently unavailable. Data related to decreasing of iron and aluminum concentration also unavailable. Therefore in depth study need to be done in term of land leaching at laboratory scale followed by adapattaion simulated with local microclimate condition. This paper present study results of leaching effectiveness of acid sulphate soil and subsequently followed by field recomendadtion based on soil watertable dynamics and rainfall condition. Adaptation toward crop at micro scale was also done on corn crop.

2. Materials and Methods

The study was conducted at Chemical, Biological and Soil Fertility Laboratory, Faculty of Agriculture, Sriwijaya University, Indralaya. The method used in this study was physical model exprimentation. Soil sample was taken from tidal lowland area of Sugihan Kanan (classified as acid sulphate soil). Equipments used in this study were 1) writing utensils, 2). Analytical equipment for determination of Al, Fe and pH 3) Siever, 4) Hoe, 5) Corong, 6) Muslin, 7) Camera, 8) plastics bag, 9) rubber, 10) Sack, 11) Meteran, 12) Paralon pipe. Materials used in this study were 1) water, 2) analytical chemicals for determination of Al, Fe and pH (pH of water and soil) and 3). Soil sample.

Leaching process requires 12 pipes as soil container having dimension 30 cm in height and 11 cm in diameter. One of pipe tips is wrapped with muslin cloth and tied using rubber bracelet. Soil sample is taken and put into each pipe with height of 20 cm or equivalent to 1.5 kg.

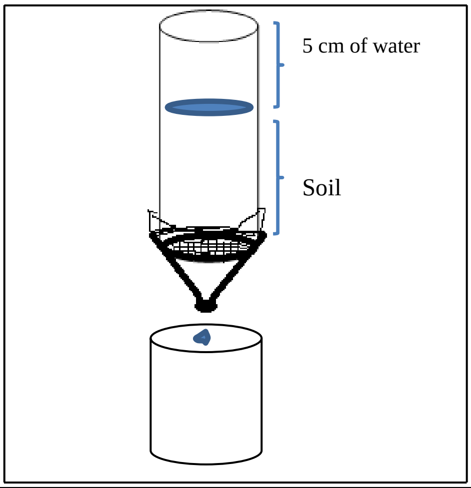

Figure 1. Schematic of Physical Model of Soil Leaching

Soil sample within pipe is added with clean water with height of 5 cm from soil surface or equivalent to 1,150 ml. Subsequently leaching process was conducted by using intermittent irigation in which water is applied into paralon tube containing soil. Initial flooding is 5 cm height of water. If surface water condition in paralon tube is no longer flooded, then water is added again until 5 cm height of water.

This study was experimental method using 4 treatments level with 3 replications so that there was 12 exprimental units as follows:

P0 = Tidal lowland soil without leaching
P1 = Tidal lowland soil with 5 times leaching within 5 days.
P2 = Tidal lowland soil with 10 times leaching within 10 days.
P3 = Tidal lowland soil with 15 times leaching within 15 days.

Soil from each exprimental unit was taken at final observation period for analyzing of Al, Fe and pH. Soil samples used for analysis are as follows: 13 samples for Al analysis; 13 samples for Fe analysis; 13 samples for soil pH analysis and 9 samples for water pH analysis which comprised total of 48 observation samples. Water from leaching process at final day of observation from each exprimental unit was collected for its pH measurement.

3. Results and Discussion

3.1. Initial Soil Characteristics

Soil for this study was taken from tidal lowland area of Bandar Jaya Village, Sugihan Kanan, Ogan Komering Ilir District. This study area is classified as tidal lowland area with C-typology in which tidal water can not flood the land. Water within channel has function to maintain soil watertable not to drop quickly. Soil physical properties was characterized by sandy loam texture at depth of 0-30 cm and it was classified as acid sulphate soil because it has sulphidic layer.

Horizon layer of sulphidic or sulphyric was found in the field at depth in the range of 60 to 70 cm below soil surface. According to [9], soil is classified as acid sulphate soil if sulphidic horizon is found at depth of 120 cm below soil surface. Acid sulphate land usually is developed at tidal lowland area having marine sediment. Characteristics of acid sulphate land is highly vary because its environment condition is also vary. Some terminologies are inherent to acid sulphate land which represent environmental condition and problems magnitude found in the field. At some soil sampling locations, there was actual acid sulphate land with sulphidic layer < 50 cm, but in general this land is classified as potential acid sulphate land because it has sulphidic layer depth > 50 cm. However, because this layer was found at 90 cm below soil surface, it was classified as degraded category and should be recovered immediately.

Soil chemical characteristic at the study area was shown in Table 2. Soil condition had some constraints for crops cultivation because it has high acidity (pH 0f 3) and iron content of 11.33 ppm as well as aluminum concentration of 100.80 ppm. Aluminum (Al) and iron (Fe) elements are toxic for crops at tidal lowland area. Aluminum (Al) and iron (Fe) are micro elements that have important function for crops. According to [10], iron (Fe) had several important functions for crop metabolisms. Metabolisms process is consisted of photosynthesis, respiration, main component of protein cells and had significant effect on quality and quantity of crop yield [11]. [12] had reported that iron toxicity was the main constraint for rice cultivation enterprise at tidal lowland area. Fe toxicity is also related to several factors such as stress of nutrients (K, P, Ca, and/or Mg) which tend to decrease capability of roots oxidation, environmental condition such as poor drainage and continuous flooding of soil as well as variety of Fe toxicity sensitive crops such as IR64 [13].

In order to reduce high level of iron precipitation, some combination measures can be conducted such as the use of tolerant or relatively tolerant varieties with improved environment of crop growth consisting of drainage improvement, balance fertilization, lime addition and organic fertilizer addition [14]. However, rainfall harvesting should also be done to substitute poor water quality at tidal lowland area of Air Sugihan [15]. Moreover, water control should be provided in tertiary channel to retain rainfall water as well as to prevent poor water quality from entering into channel.

Table 1. Data of soil pH, water pH, Aluminum (Al), Iron (Fe) and Soil Texture in the Field

Sample	Soil pH	pH H_2O	Fe (ppm)	Al (ppm)	Texture
Air Sugihan	Quarterly channel : 3.44	3.88	11.31	100.80	Sandy loam

Tertiary channel: 3.07

[16] had reported that iron toxicity was the main constraint for rice cultivation enterprise at tidal lowland area. Fe toxicity is also related to several factors such as stress of nutrients (K, P, Ca, and/or Mg) which tend to decrease capability of roots oxidation, environmental condition such as poor drainage and continuous flooding of soil as well as variety of Fe toxicity sensitive crops such as IR64 [17].

In order to reduce high level of iron precipitation, some combination measures can be conducted such as the use of tolerant or relatively tolerant varieties with improved environment of crop growth consisting of drainage improvement, balance fertilization, lime addition and organic fertilizer addition [18]. However, rainfall harvesting should also be done to substitute poor water quality at tidal lowland area of Air Sugihan [19]. Moreover, water control should be provided in tertiary channel to retain rainfall water as well as to prevent poor water quality from entering into channel.

3.2. The Effect of Soil Leaching on Soil Acidity Status

The effect of soil leaching period on the change of soil acidity showed significant effect quantitatively from initial pH of 3.8 to 4.3 (Figure 1). However, pH qualitatively was classified as very acid because it was lower than 4.5. Thus, soil leaching process had little effect on increasing of soil pH. Soil acidity status had pronounced effect on availability of soil nutrients. Therefore, this parameter is limiting factor for crops growth and production. The minimum threshold value of pH was 5.5 because optimum condition for several soil nutrients was affected by pH. For pH value less than 5.5, phosphate ions are fixed by Fe and Al as water-insoluble compound, whereas phosphate ions will react with Ca and Mg to form water-insoluble compound at pH value above 7.0 so that phosphorous nutrient (P) is unavailable for crops [20]. Therefore, soil condition in this case still needs amelioration in addition to soil leaching.

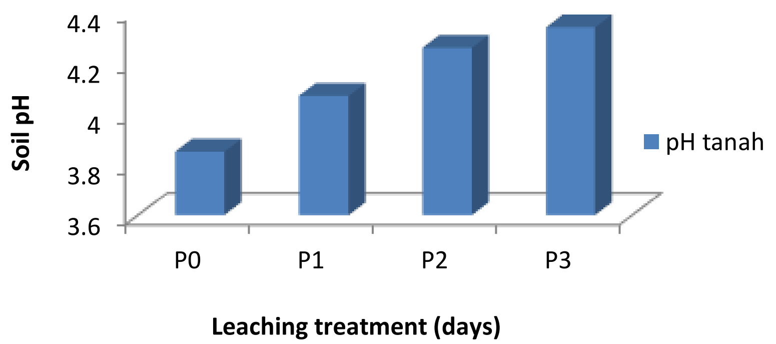

Figure 2. The effect of leaching period on soil pH increase

Soil acidity status is very important factor because it affects soil nutrients such as phosphorous availability. [21] had reported that measure to increase soil pH through liming was capable to decrease P-fertilizer requirement up to 62%. In addition, absorption of P element has maximum value up to 0.736% at soil condition with pH of 6 or relatively acid [22].

High level of soil acidity also has effect on N element absorption of soil. At soil pH of 6.0, N nutrient absorption was high with magnitude of 3.702% [23]. At low soil pH, nutrients absorption and availability was low. This is due to the fact that H^+ ions had filled negative charges area within soil particles which in turn replace the position of nutrients availability. Measures to increase soil acidity generally were done by lime addition. Some examples of lime are calcium carbonate, calcium oxide (CaO) and calcium hydroxide ($Ca[OH]_2$). Carbon dioxide within soil reacts with water to produce bicarbonate (HCO_3^-) and hydroxide (OH^-) which capable to take H^+ ions and aluminum (acid-forming cations) ions come out from solution and subsequently capable to increase soil pH [24]. In addition, Bahtiar (2008) had stated that lime types of carbonate group such as calcite ($CaCO_3$) and dolomite

($CaMg(CO_3)2$) were common lime used in the field. The increase of soil pH was due to dissociation of these carbonate group into Ca^{2+}, Mg^{2+} and CO_3^{-2} ions within soil.

According to [25], the study of soil liming at tidal lowland area of Banyu Urip Village showed that soil liming was capable to increase soil pH with magnitude of 5.36 by using lime dose of 2.5 tones.ha^{-1} or at least farmers used lime dose of 1.5 and 2 ton.ha^{-1}. The increase of soil pH through lime addition is due to the increase of Ca^{2+} ions concentration within soil. The increase of Ca^{2+} ions produce neutralization effect due to substitution reaction of H^+ ions with Ca^{2+} ions [26].

3.3. The Effect of Leaching on the Decrease of Iron Concentration.

Iron toxicity on crop cultivation, especially rice, is frequently found at tidal lowland agriculture. High concentration of iron results in unbalance condition of nutrient and capable to decrease crop production from 10% up to 100% [27]. The effect of land leaching treatment on the decrease of iron concentration was hown in Figure 3.

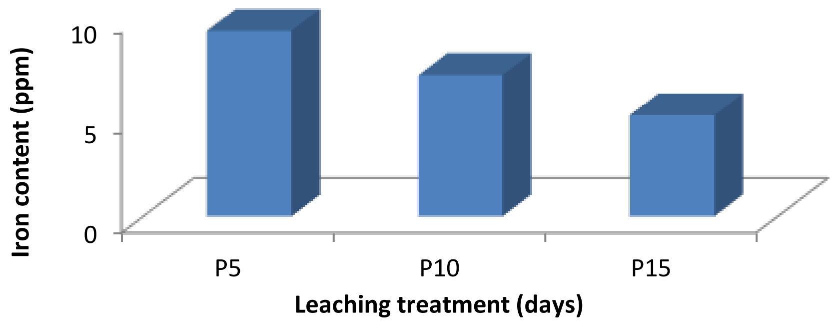

Figure 3. The decrease of iron content due to several leaching treatments

[28] had reported that iron concentration at tidal lowland area of Blandean and Puntik Dalam, Barito Kuala District, was very high in the range of 407.61 to 699.0 ppm. This condition is very harmful for crops. On the contrary (Figure 2), condition of iron concentration at Sugihan area of South Sumatra that had received leaching treatment was only in the range of 5 to 10 ppm. Average decrease of iron concentration was 0.4 ppm for every leaching reatment. Moreover, [29] had stated that improvement water management system in the field for rice cultivation at tidal lowland area was capable to decrease iron concentration from 78.68 ppm to 41.31 ppm.

Iron precipitation was determined by the range of pH value and redox potential. This redox potential will determine whether iron will experience oxidation reaction or reduction reaction. At condition of medium acidity, FeOOH will soluble into Fe2+, whereas Fe3+ will dominant at very oxidative condition with redox potential value >400 mV and pH < 2. The stable form of iron is Fe2+. Siderit ($FeCO_3$) was formed at condition of medium reduction and pH >7. According to Kirk (2004), iron will be stable at very reductive condition.

Fe concentration within solution results in toxicity on rice at various levels. [30] had reported that Fe concentration within solution that capable to produce toxicity effect was in the range of 10 to 500 ppm. Results study from [31] showed that Fe concentration within nutrient solution with magnitude of 250-500 ppm at pH condition of 4.5-6.0 had significantly increase Fe concentration within rice crop tissue and showed Fe toxicity symptoms on crop.

Fe concentration within solution that was higher than 250 ppm showed Fe toxicity symptoms and the decrease of rice growth. In addition to high concentration of Fe within solution, Fe toxicity was also affected by pH of solution [32]. The critical threshold of Fe concentration within soil solution was also affected by soil pH. Fe toxicity was occurred at Fe concentration of 100 ppm at pH 3.7 and at Fe concentration of 300 ppm at pH 5.0 [33]. The study by [34] showed that Fe concentration of > 200 ppm within solution had caused rice growth retardation, whereas Fe concentration of 600 ppm within solution had caused the death of rice crop.

3.4. The Effect of Leaching Treatment on the Decrease of Aluminum Content

Aluminum content at tidal lowland area is frequently considered as the main constraint factor in crop cultivation. Aluminum content was still very high although soil had received leaching treatment (76.99 ppm). This fact showed that leaching treatment had no significant effect on aluminum content.

Table 2. Soil Aluminum (Al) content after leaching treatment (ppm)

Leaching Time	Replication				
(Days)	1	2	3	Total	Average
0 (P_0)	65.62	72.97	73.67	212.26	70.75
5 (P_1)	94,32	110.07	81.02	285.41	95.13
10 (P_2)	91,87	98.87	88.02	278.76	92.92
15 (P_3)	68.07	82.60	80.32	230.99	76.99

Soil leaching experiment at acid sulphate soil conducted by [35] showed that exchangeable aluminium concentration before treatment was 4.10 me/100g (medium). Leaching treatgment in the field with spacing of 3 m between channels (intensive) was capable to decrease aluminium concentration into 3.80 me/100g. However, there was no significant change at channel spacing more than 3 m. This condition showed that input in forms of soil conditioner and amerliorant are needed for acid sulphate soil in order to decrease aluminum content.

In term of crop growth, for example soybean, crop growth will be optimum at aluminum concentration less than 20 ppm [36]. However, crop can still grow up to aluminum concentration of 40 ppm [37]. Therefore, land drainage improvement at acid sulphate land should be accompanied by dolomite lime addition at minimum dose of 1 ton.ha-1 [38]. The study conducted by [39] showed that application of dolomite lime at dose of 1 ton.ha-1 combined by manure at dose of 2.5 ton.ha-1 was capable to produce soybean yield of 2.4 ton.ha-1. In addition, improvement of soil fertility and soil physical condition through application of soil conditioners can be done by using biochar. Application of coconut shell biochar at dose of 15 ton.ha-1 was capable to increase soil organic matter and rice production with magnitude of 1-2 ton.ha-1 [40].

3.5. Land Leaching Strategy in Field

Land leaching in field will be proper if water was available in sufficient amount in tertiary plot. High tidal water can not enter the land for area having high topography such as C typhology. On the other hand, rainfall water is only capable to wet soil surface. Therefore, the most important step is to increase soil water table height so that rainfall water can be hold as much as possible and capable to flood the land. In order to apply land leaching model, rainfall water should be able to flood the land at least at 5 cm above soil surface.

Soil porosity usually is characterized by high values of hydraulic conductivity and porosity resulting in high water lost. Soil porosity value at the study area (Bandar Jaya Sugihan) in average was 50.43% so that soil capability to store water at depth of 100 cm was 504.3 mm. Opportunity potential for land leaching should take into account rainfall data and watertable surface fluctuation for one year period (Figure 5). During long dry season, water table drawdown at C typhology land was very deep up to 120 resulting in phyrite oxidation. Leaching process was only conducted by utilizing rainfall water during soil tillage in November to October.

Watertable surface at November was at average depth of 40 cm so that one time land leaching requires water quantity of 40 cm x 400 mm = 201.72 mm. At least 5 times leaching is required from results of laboratory research. Monthly rainfall condition (Figure 3) showed that rainfall quantity in November was in the range of 200 to 400 mm. This rainfall quantity is only sufficient for one to two times leaching. Farmers at December had already conducted seeds sowing so that land leaching can not be conducted because water is required to fill soil pores in order to develop saturated water condition. High tidal water from secondary channel can be used only to fill water in tertiary channel. Figure 4 showed soil watertable dynamics at land of C-typhology in Delta Saleh Primer 10 at rainfall condition and water is retained within tertiary channel. Watertable at this condition can move up to 20 cm below soil surface [41]. Therefore, land leaching can be conducted two times druing November period having normal rainfall and rainfall water at October period can be used to refill soil watertable. Thus, leaching frequency can be improved by using micro water management.

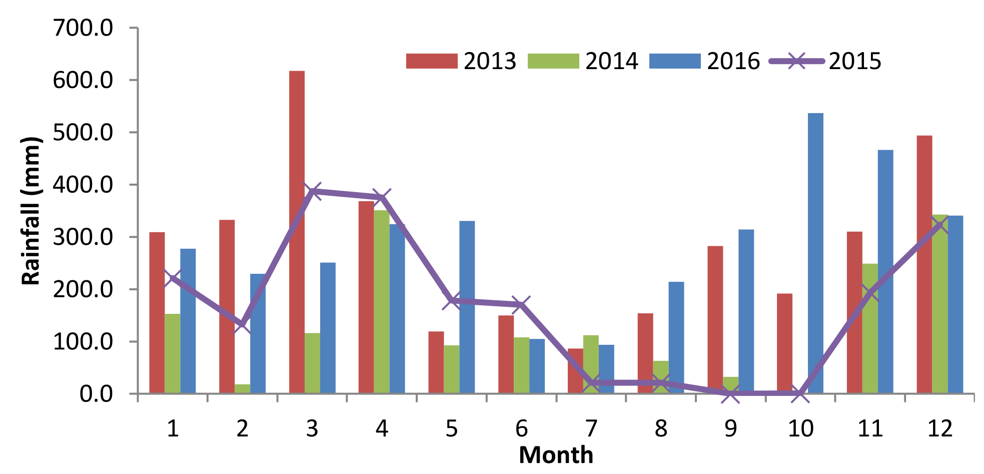

Figure 4. Rainfall distribution at study area during 4 years

However, lime addition is still required at initial stage of remediation process for tidal lowland of C-typhology in order to accelerate the decreasing of aluminum and iron concentrations and to increase soil pH. Land remediation process by using leaching system is conducted continuously and it is estimated that this process requires 3 to 5 years. Liming is not required as long as phyrite layer is not oxidized. However, Figure 4 showed that soil watertable surface at dry season was always located below phyrite layer so that oxidation process is always occurred. [42], phyrite at this condition becomes unstable with the availability of oxygen which in turn had changed Fe3+ and SO42- solubility into jarosit or goethite and the final product from this reaction is the formation of H+ ions that decrease soil pH. In addition, crack in soil will develop and increase of toxic elements such as Al3+, Fe3+, sulphide, and organic acids as the main problem for low soil fertility at tidal lowland area [43].

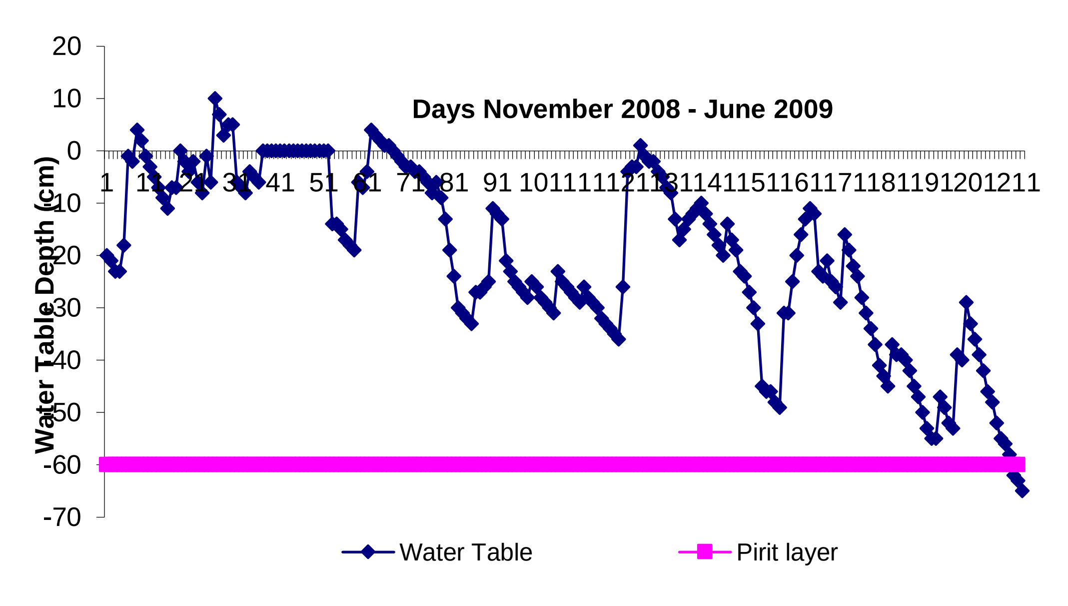

Figure 5. Soil watertable dynamics at Delta Saleh Primary 10 [44]

The impact of phyrite oxidation had caused low availability of phosphate element as the main problem of crop cultivation at tidal lowland area. The oxidized phyrite results in very acid soil and nutrients deficiency, especially P, due to fix up by iron oxides such as goethite and hematite. In addition, the final product from phyrite oxidation is the formation of H+ ions resulting in decrease of soil pH and subsequently some of these ions are used to oxidize Fe2+ to Fe3+ [45]. According to [46], abundant quantity of H+ ions within soil solution will destroy clay mineral structure which in turn releases many aluminum ions (Al3+) that are toxic for crops. Therefore, utilization of acid sulphate soil was done by maintaining phyrite layer in unoxidized condition. Thus, water retention measure in channels is very important to prevent quick drawdown of soil water table [47].

3.6. Crop Adaptation at Greenhouse Scale

Soil that had received leaching treatment was subsequently composited from each replication with the same treatment into polybag which contain 4 crops. Observation of corn crop height was done three times when crops old are 10 DAP (Days After Plantng), 15 DAP and 20 DAP, respectively. Average height of crops after receiving leaching treatment was shown in Table 3.

Table 3 showed that several leaching treatments had no significant effect on corn crop height. The highest crop height was found on 5 days leaching treatment with average height of 35.1 cm, 15 days leaching treatment had produced average crop height of 34.3 cm, 10 days leaching treatment had produced average crop height of 33.6 cm and without leaching treatment had produced average crop height of 32.2 cm, respectively.

Table 3. Crop height after planted in leached soil

	Crop height (cm) – days		
Leaching treatment (Days)	10 DAP	15 DAP	20 DAP
Without leaching	10.3	30.5	56
5	11.2	32	62
10	10.5	31.5	58,8
15	12	31	60

The results showed the trend that the longer the soil leaching treatments, the higher the crop height. However, 5 days leaching treatment had produced the highest crop height compared to 15 days leaching treatment. This was estimated that 5 days leaching treatment contain more nutrients required by corn crop due less leaching effect such as soil bases. According to [48], soil bases generally are easily leached so that soil with high base saturation showed that it is experience less leaching and classified as fertile soil. In addition, environmental factor also has significant effect on crop height [49].

According to [50], crop growth is affected by climatic factors such as water, air, sunlight, wind and length of day. Corn crop having height of 1-3 m is considered as ideal crop height to produce the maximum yield. The study results from [51] showed that crop height has no relation to the yield or productivity of corn crop. [52] also stated that crop growth rate is vary depending on soil humidity, soil fertility and crop variety.

Analysis of soil before and after leaching treatment had provide information related to the effect of Al, Fe and pH on corn crop. According to [53], aluminum (Al) toxicity had effect on soil pH. If soil pH is less than 5, then aluminum (Al) toxicity will occur. Symptoms of aluminum (Al) toxicity on plants are as follows: abnormal roots growth, short and thick roots, and chlorosys between old leave bones having white/yellow in color. Aluminum (Al) concentration within soil solution is very high when soil pH is low. The value of pH is increasing in flooding soil and Al concentration within soil solution is decreasing below critical level of Al toxicity.

Iron reduction is the most important reaction in flooded acid soil because it is capable to increase pH and P availability as well as replace other cations from exchanging site such as K+. The increase of Fe2+ concentration in acid soil can results in iron toxicity for rice crop if Fe2+ concentration within soil solution is equal to 300 ppm. Iron concentration within soil solution is governed by soil pH, organic matter content, iron content and length of leaching and flooding. The increase of Fe2+

concentration is due to reduction of Fe^{3+} into Fe^{2+}. According to [54], organic matter can stimulate Fe^{3+} reduction resulting in increase of Fe^{2+} concentration.

Iron controlling strategy and increasing of rice production at location having problem with Fe toxicity (Fe stress) are depend on the main cause of toxicity occurrence on crops. According to [55], measures to control Fe toxicity and increasing of rice production on land having Fe toxicity can be done through water management technology such as drainage improvement, balance fertilizing, organic matter addition and lime addition. In addition to cultivation technology and soil and water management, the use of tolerant or relatively tolerant varieties is more effective in controlling iron toxicity. The use of rice varieties should be adjusted to rice capability to adapt to the specific environment. The use of tolerant varieties is the cheapest and the easiest way applied by farmers, but to produce tolerant varieties with high yield is very difficult and require long time. Improvement of growth environment where crops are capable to grow optimally and give high yield by using intolerant varieties requires high input so that production cost becomes high. In order to control Fe toxicity and increasing of rice production can be done by combining tolerant or relatively tolerant varieties and improvement of growth environment. Varieties having high yield potential that are relatively tolerant to Fe toxicity can be used at environment with low Fe stress. Varieties having high yield potential that are tolerant or relatively tolerant to Fe toxicity combined with growth environmental improvement with low input can be used at environment with medium Fe stress. Fe tolerant variety combined with growth environmental improvement should be used at environment with heavy Fe stress.

The study results from [56] showed that six times leaching with application interval 10 days during land preparation can accelerate oxidation and leaching of toxic elements from tilled layer soil; subsequently S-phyrite and Fe^{2+} are leached and their concentration were low. The highest yield was obtained at treatment combination of leaching and 30 cm tilled layer soil (3.42 ton ha^{-1}).

4. Conclusions

Land quality at tidal lowland area can be improved by land leaching process. Experiment at laboratory showed that soil leaching intensity had significant effect on increasing of pH and decreasing of iron concentration. Treatment of 15 times leaching showed good result, but not significantly different than 5-10 times leaching treatments. It means that field leaching process should be conducted during land preparation within 2 weeks period. In term of land preparation period in November, rainfall at tropic area was sufficient to fulfill leaching water requirement, then adaptation of crop growth on soil with 5 times leaching frequency showed the best result. Therefore, field leaching should be done 5 times using flushing process with channel water.

Acknowledgments

This research was funded by research competitive of Sriwijaya University with contract number 0179.033/UN 9/SB 3. LPPM.PT/2020. We would like to say thank you for everybody who has supported this research since the site selection, implementation and funding.

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