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Optimization of Groundwater Level and Organic Mulch Application on The Chemical Properties of Peat Soil

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ABSTRACT

As agricultural land, Peat has various obstacles; one problem is the decreased groundwater level. This can have an impact on the availability of nutrients in the soil. Therefore, water management is an absolute necessity for agricultural activities on peatlands. Another effort that can be made to increase the fertility of peatlands as agricultural land is to use organic mulch. This study aims to analyze the effect of peat water level and application of organic mulch on the chemical properties of peat soil planted with corn. This research was conducted in Air Terbit Village, Riau Province, and the Soil Laboratory, Faculty of Agriculture, University of Riau, from February to July 2021. This research used a factorial complete randomized design (CRD) method consisting of 2 factors. The first factor was the various heights of the groundwater level (GWL) which consisted of 3 levels (30 cm, 40 cm, and 50 cm), while the second factor was various types of organic mulch (without mulch, the mulch of empty oil palm bunches, the mulch of rice straw and the mulch of corn stover). Parameters observed were pH, C-organic, N-total, P-available, CEC, and bases (Ca, K, Mg, Na). The results showed that the GWL 30 cm treatment and rice straw mulch increased the pH, Ca, and Mg values better than the other treatments. The N element also increased at GWL 30 cm. In general, the two treatment factors also increased the values of P, CEC, and Na in some experimental units. C-organic and K values decreased after the treatment compared to the soil criteria before treatment.

Keywords*: Groundwater Level, Organic Mulch, Soil Chemical Properties, Peat Soil, Decomposition*

1. INTRODUCTION

In Indonesia, peat land covers 6.66% (12.532.422 ha) of the total land area. Riau Province is one province that extensively uses peatlands as agricultural land. Riau Province's peatland area is 3.573.955 hectares (BBSDLP, 2020). Peat as agricultural land presents some challenges, including the drop in groundwater level, which can exacerbate fires, particularly during the dry season. Meanwhile, the area is prone to high waterlogging due to sinking of the soil surface. 2019 (Putra and Lasmana). This can affect nitrogen availability in the soil. Wawan et al. (2019) discovered that the total N-content of peat soil was 0.84% at a water level of 2040 cm and 0.94% at a water level of 4060 cm in their research on peat soils with groundwater level regulation. Furthermore, Simatupang et al. (2018) found that water level substantially affected soil temperature. According to his findings, a groundwater level of 30 cm has an average soil temperature of 29.3°C greater than 50 cm, 27.67°C, and 80 cm, which is 27.33°C.

Organic mulch is another effort that may be made to promote raising the fertility of peatlands as agricultural land. According to Moelyohadi (2017), applying organic matter has good impacts, such as improving the availability of macro and micronutrients in the soil and providing energy for the activities of soil microorganisms.

Organic matter can be obtained from various sources, including plant waste. Organic mulch supplies include trash from empty palm oil bunches, rice straws, and maize stover. According to the findings of Lasmini et al. (2018), the application of rice straw mulch had a good influence on the soil, increasing N-total from 0.12% to 0.54%. According to Suryantini and Setiawan's (2016) research, the findings of an analysis of corn plant waste compost were N = 3.37%, P = 0.86%, K = 2.27%, and Ca = 3.86%, indicating that corn plant waste has the potential to be an extra nutrient element in the soil. Meanwhile, in this study, maize plant waste was used directly as mulch.

This study aims to investigate the impact of peat water level and organic mulch application on the chemical characteristics of peat soil.

2. MATERIAL AND METHODS

This study was conducted in Air Terbit Village, Kampar District, Riau Province. Soil chemical characteristics were examined at the Soil Laboratory, Faculty of Agriculture, University of Riau. The study was carried out between February and July of 2021.

The study included empty palm oil bunches, rice straws, maize stover, peat soil, and peat water. Soil samples, distilled water, buffer solutions pH 7.0 and pH 4.0. H2SO4. 40% NaOH, boiling stone powder, 1% boric acid, Conway indicator, Bray and Kurt I extractors, phosphate dyes, ammonium acetate, 70% alcohol, and 1 N KCl were used to analyze the chemical properties of the soil. Polybags measuring 40 x 60 cm, buckets measuring 53 x 30 cm, a chopping machine, gauze nets measuring 50 mesh, nylon thread, and needles were utilized in this study. sew. Analytical scales, measuring cups, plastic bottles, sieve shakers, pH meters, porcelain dishes, furnaces, Kjeldahl flasks, electric stoves, boiling flasks, destilators, Erlenmeyer, burettes and statives, whatman paper, funnels, pipette s, test

tubes, test tube racks, vortexes, and spectrophotometers are among the tools used to analyze the chemical properties of soil.

A factorial, fully randomized design (CRD) with two components was employed in this study. The first factor is the groundwater table's different heights, divided into three levels: 30 cm high, 40 cm high, and 50 cm tall. The second component is using various organic mulches, including no mulch, mulch made from empty palm oil bunches, mulch made from rice straw, and mulch made from maize stover. Each element was combined to create 12 treatment combinations, and each treatment was performed three times for a total of 36 study units.

The experiment was carried out by inserting polybags filled with soil in buckets perforated according to TMA level. Furthermore, the bucket is filled with peat water, and if the groundwater level drops, water is added to the bucket to comply with the treatment. After the treatment, the mulch deposited in the litter bag is then applied to the ground. Each bag has 251.2 g of mulch in it. After 70 weeks of field research, roughly 20 g/polybag soil samples were collected for laboratory investigation of soil chemical characteristics.

pH, organic-C, total-N, available-P, CEC, and bases (Ca, K, Mg, Na) were all measured. The gathered data were statistically evaluated using Analysis of Variance (ANOVA). If the variance findings differ considerably from the treatment, Duncan's Distance Test is performed at the 5% level. Figure 1 illustrates the application of groundwater-level treatment, while Figure 2 shows the application of various forms of organic mulch.

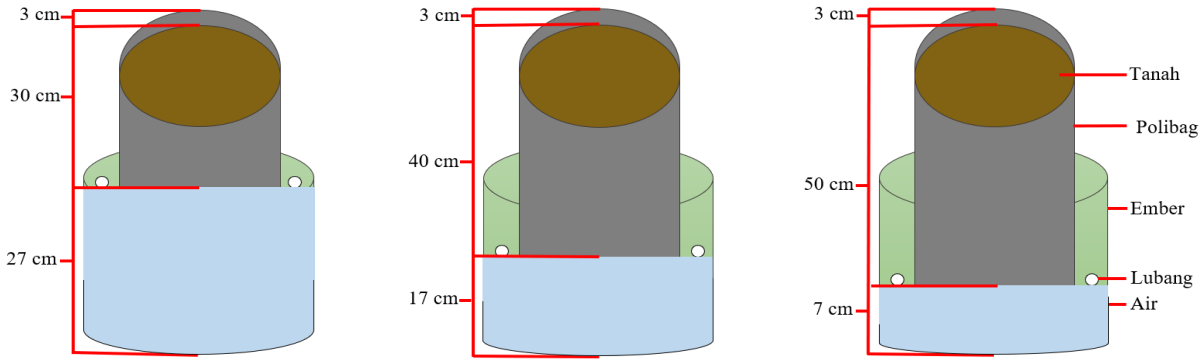

Figure 1. Application treatment of various groundwater levels (A) TMA 30 cm; (B) TMA 40 cm; (C) TMA 50 cm

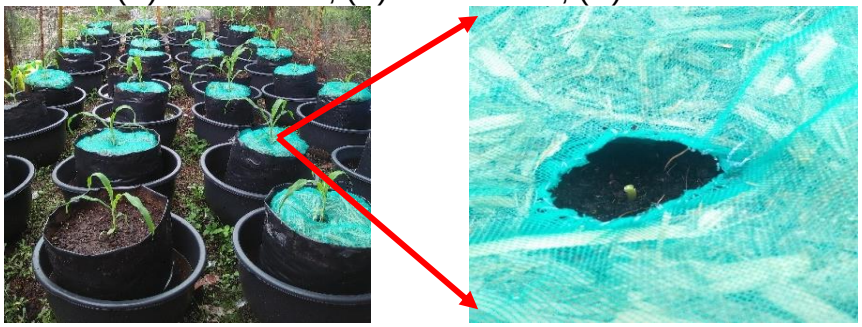

Figure 3.2. Organic mulch application

3. RESULT AND DISCUSSION

Characteristics of Initial Soil Chemical Properties

The initial soil chemical properties were analyzed to determine changes in soil chemical properties before and after the treatment was applied. The chemical characteristics of the soil before TMA treatment and the application of various types of organic mulches are presented in Table 1.

Table 1. Characteristics of Initial Soil Chemical Properties begore treatment

Chemical Properties	Value	Category
pH	4.94	Acid
C-organic	49.40%	Extremely High
N-total	0.19%	Low
P-available	167.06 ppm	Extremely High
KTK	78.57 me/100 g	Extremely High
Ca	17.47 me/100 g	High
K	1.91 me/100 g	Extremely High
Mg	5.20 me/100 g	High
Na	0.65 me/100 g	Medium

The soil's acidity level before treatment was 4.94, classified as acid. This number is relatively high when compared to the average pH of peat in Indonesia, which is pH 4 (Yuningsih et al., 2019). Furthermore, available P is extremely high. The high pH and accessible P are assumed to result from prior agricultural cultivation on the area, such as applying an ameliorant.

Peat soil has an extremely high C-organic content, reaching 49.40%. These findings are consistent with those of Permatasari et al. (2021), who discovered that C-organic at their research areas ranged from 53.29-56.07%. The high C-organic content of peat soil is due to the source of its constituent ingredients, which are plants that contain organic matter.

The total N-content of the soil is low, namely 0.19%. According to Prayoga et al. (2022), a decrease in N can occur due to the degradation of organic matter and the still acidic pH. This causes microorganisms to decompose soil organic matter and fix N not to work optimally.

Meanwhile, CEC and soil bases exhibited high to extremely high values before treatment. Kurniawan et al. (2020) state that a high CEC has a very high peat adsorption capacity but a weak adsorption strength, which means that even though the cations K, Ca, Mg, and Na are classed as medium to very high, they will be easily leached.

Acidity Level (pH)

The results of variance indicated that the treatment of various groundwater levels and the application of different types of mulch each had a significant effect on pH. However, there was no interaction between the two treatments. The results of Duncan's Advanced Test at the 5% level are presented in Table 2.

Table 2. pH at various groundwater levels and the application of various types of organic mulch

Water Level	Organic Mulch				Mean
	TM	TKKS	JP	BJ	
30 cm	5.85	5.72	6.02	5.68	5.82[a]
40 cm	5.13	5.52	5.64	5.43	5.43[b]
50 cm	5.20	5.37	5.73	5.84	5.53[b]
Average	5.39[b]	5.54[ab]	5.79[a]	5.65[ab]	

Note: Different superscripts in the same row or column show significant differences according to Duncan's Distance Test at the 5% level.
TM = without mulch; EFB = empty fruit bunches of oil palm; JP = rice straw; BJ = corn stover.

The pH value of all experimental units increased from the initial pH of 4.94. The highest pH value was significantly 5.82 at TMA 30 cm. The acidity level of peat soil is affected by the content of organic acids, namely humic acid and fulvic acid, which dissolve in water (Sari et al., 2020). Therefore, the more water in the soil, the easier it is for organic acids to dissolve so that the soil pH increases.

On the organic mulch application factor, the highest pH was the application of rice straw mulch, namely 5.79. However, applying organic mulch generally has a positive effect on increasing pH. This indicates a link between mulch as a food source for cellulolytic microbes and their activity in breaking down organic matter. This is following the statement of Murnita and Taher (2021), the organic matter added will decompose or mineralize, releasing minerals in the form of basic cations (Ca, Mg, Na, K), which cause the concentration of OH ions to increase, this causes the pH to rise.

Carbon (C-organic)

The variance results revealed that different groundwater levels substantially affected C-organic. Meanwhile, the use of various types of organic mulch alone, the combination of treatments involving the height of the groundwater and the use of various types of organic mulch, had no discernible effect. Table 3 shows the findings of Duncan's Advanced Test at the 5% level.

Table 3. C-organic at various groundwater levels and applications of various types of organic mulches (%)

Water Level	Organic Mulch				Mean
	TM	TKKS	JP	BJ	
30 cm	38.45	40.78	42.71	38.36	40.07[a]
40 cm	37.11	38.11	34.59	39.05	37.21[b]
50 cm	42.82	43.37	41.63	39.24	41.76[a]
Average	39.46	40.75	39.64	38.88	

Note: Different superscripts in the same row or column show significant differences according to Duncan's Distance Test at the 5% level.
TM = without mulch; EFB = empty fruit bunches of oil palm; JP = rice straw; BJ = corn stover.

Only the height of the groundwater has a substantial effect on C-organic, as seen in Table 3. The highest C-organic value, 41.76%, was found at 50 cm TMA.

The C-organic value of the soil was known to decrease overall in each experimental unit compared to the original soil (49.40%) after treatment. Element C is depleted because it is commonly used as a source of energy by organisms. This is consistent with the findings of Istina et al. (2019), who found that increasing soil pH led in degrading microbial activity capable of decomposing utilizing peat organic matter as an energy source, resulting in the release of carbon in the form of CO2 into the atmosphere.

Nitrogen (N-total)

The variance test results indicated an interaction between the treatments of various groundwater levels and the application of different types of organic mulches. Treatment of various groundwater levels and applying multiple types of organic mulches also significantly affected N-total. The results of Duncan's Advanced Test at the 5% level are presented in Table 4.

Table 4. N-total at various groundwater levels and applications of different types of organic mulches (%)

Water Level	Organic Mulch				Mean
	TM	TKKS	JP	BJ	
30 cm	0.92^{ab}	0.49^{e}	0.85^{bc}	1.16^{a}	0.85^{a}
40 cm	0.65^{cde}	0.86^{bc}	1.00^{ab}	1.03^{ab}	0.88^{a}
50 cm	0.57^{de}	0.46^{e}	0.42^{e}	0.81^{bcd}	0.56^{b}
Average	0.71^{bc}	0.60^{c}	0.76^{b}	1.00^{a}	

Note: Different superscripts in the same row or column show significant differences according to Duncan's Distance Test at the 5% level.
TM = without mulch; EFB = empty fruit bunches of oil palm; JP = rice straw; BJ = corn stover.

Table 4 demonstrates that the overall N-total has increased. The 30 cm TMA interaction with corn stover mulch application had the highest N-total value of 1.16%, whereas the 50 cm TMA interaction with rice straw mulch application had the lowest of 0.42%. Based on the findings of the N-total analysis, which showed 0.19% in the initial soil sample, it can be concluded that the TMA treatment and the application of organic mulch can raise the N element in the soil from low to moderate to extremely high. According to Suanda et al. (2022), organic matter is a source of total N, so the higher the organic matter in the soil, the more available N content will also increase. (Wijanarko et al. (2012) explained that during the decomposition of organic matter, microorganisms will first utilize N for their living needs and then release it into the soil through a secretion process.

Fosfor (P-available)

The variance results indicated a significant interaction between the various TMA soil treatments and the application of various types of organic mulches. The treatment of various groundwater levels and the application of various types of organic mulches each also significantly affected the available P value. The results of Duncan's Advanced Test at the 5% level are presented in Table 5.

Table 5. P-available at various groundwater levels and applications for multiple types of organic mulch (ppm)

Water Level	Organic Mulch				Mean
	TM	TKKS	JP	BJ	
30 cm	131.65^{f}	101.06^{f}	200.07^{e}	221.00^{e}	163.44^{c}
40 cm	127.63^{f}	341.85^{b}	252.50^{d}	207.05^{e}	232.26^{b}
50 cm	466.01^{a}	127.75^{f}	310.79^{c}	199.37^{e}	275.98^{a}
Average	241.76^{a}	190.22^{c}	254.45^{a}	209.14^{b}	

Note: Different superscripts in the same row or column show significant differences according to Duncan's Distance Test at the 5% level.
TM = without mulch; EFB = empty fruit bunches of oil palm; JP = rice straw; BJ = corn stover.

The interaction of the two treatments produced the maximum output, 466.01 ppm in the 50 cm TMA treatment without mulch and 101.06 ppm in the 30 cm TMA treatment with OPEFB mulch application. This is consistent with Fahmi et al. (2014)'s explanation that a reduction in the groundwater table increases the concentration of P via the peat mineralization process. Meanwhile, organic matter is the primary P source in peatlands, with basic sulfide minerals, continuously added from plant leftovers and organisms. Most residual P in plant litter above the soil surface is then delivered to the soil in a form available to plants and soil microorganisms.

The initial soil study results revealed that the soil contained exceptionally high P, specifically 167.06 ppm, even after treatment. According to Siregar et al. (2021), the P dissolution rate in soil is relatively sluggish compared to other esters, causing this compound to accumulate significantly. High Ca and Mg elements can bind to P elements already present in peat soils.

Cation Exchange Capacity (KTK)

The variance test results revealed an interaction between the treatment combinations for various groundwater levels and the application of various organic mulches. Meanwhile, the treatment of multiple groundwater levels and the application of different types of organic mulches substantially impacted the value of CEC. Table 6 shows the findings of Duncan's Advanced Test at the 5% level.

Table 6. CEC at various groundwater levels and applications of various types of organic mulches (me/100 g)

Water Level	Organic Mulch				Mean
	TM	TKKS	JP	BJ	
30 cm	111.35^{b}	77.25^{e}	64.87^{f}	86.45^{d}	84.98^{a}
40 cm	97.49^{c}	41.49^{g}	68.74^{f}	65.91^{f}	68.40^{c}
50 cm	69.25^{f}	123.36^{a}	71.82^{ef}	47.70^{g}	78.03^{b}
Average	92.69^{a}	80.70^{b}	68.48^{c}	66.68^{c}	

Note: Different superscripts in the same row or column show significant differences according to Duncan's Distance Test at the 5% level.
TM = without mulch; EFB = empty fruit bunches of oil palm; JP = rice straw; BJ = corn stover.

The greatest CEC value by interaction was 123.36 me/100 g at 50 cm TMA with OPEFB mulch application, and the lowest was 41.49 me/100 g at 40 cm TMA with OPEFB mulch application. The soil CEC values appeared to change, with CECs lower or greater than the initial soil study results, namely 78.57 me/100 g. The overall CEC value of the soil is still included in the very high requirement. The increased CEC in soil is due to the high C-organic content. CEC has a positive relationship with the availability of organic matter in the soil. The increase in humus due to the high amount of organic matter results in the amount of soil colloids increasing so that the CEC in the soil will have a high nutrient status (Jawang, 2021). This is supported by the statement of Kurniasari et al. (2021) that the high CEC in peat is caused by the high content of soil organic matter composed of lignin fractions and humic compounds.

Calcium (Ca)

The variance test results indicated an interaction between the treatments of various groundwater levels and the application of different types of organic mulches. The treatment of multiple groundwater levels and the application of various types of organic mulches, each also significantly affected Ca. The results of Duncan's Advanced Test at the 5% level are presented in Table 7.

Table 7. Ca at various groundwater levels and applications of different types of organic mulches (me/100 g)

Water Level	Organic Mulch				Mean
	TM	TKKS	JP	BJ	
30 cm	32.45^{a}	25.69^{bcd}	28.44^{b}	25.38^{bcd}	27.99^{a}
40 cm	20.75^{e}	24.73^{cd}	27.94^{bc}	25.45^{bcd}	24.72^{b}
50 cm	22.55^{de}	22.72^{de}	26.99^{bc}	27.13^{bc}	24.85^{b}
Average	25.25^{b}	24.38^{b}	27.79^{a}	25.99^{ab}	

Note: Different superscripts in the same row or column show significant differences according to Duncan's Distance Test at the 5% level.
TM = without mulch; EFB = empty fruit bunches of oil palm; JP = rice straw; BJ = corn stover.

By interaction, the highest Ca was found in TMA 30 without mulch, 32.45 me/100 g, while the lowest was 20.75 me/100 g in TMA 40 cm without mulch. Elemental Ca increased significantly in each experimental unit compared to the Ca content in the initial soil, which was 17.47 me/100 g. According to Permana et al. (2017), the element Ca belongs to the primary mineral group feldspar (easily weathered). Feldspar is found in almost all types of soil, but its content varies according to the degree of weathering and development of the soil. Plagioclase weathering is important to the provision of Ca in the soil. This condition can also explain why Ca in the soil is always in a higher concentration than Mg and K. According to (Fibrianti, 2018), high Ca+2 saturation indicates a good pH for plant growth and microbial activity.

Callium (K)

The variance test results indicated an interaction between the treatments of various groundwater levels and the application of different types of organic mulches. The treatment of multiple groundwater levels and the application of multiple types of organic mulches, each also significantly affected K. Duncan's Advanced Test Results at 5% level are presented in Table 8.

Table 8. K at various groundwater levels and applications of different types of organic mulches (me/100 g)

Water Level	Organic Mulch				Mean
	TM	TKKS	JP	BJ	
30 cm	0.56^{h}	1.48^{b}	1.17^{d}	0.88^{e}	1.02^{b}
40 cm	0.66^{fgh}	0.74^{fg}	0.93^{e}	0.76^{f}	0.77^{c}
50 cm	0.64^{gh}	1.37^{c}	1.62^{a}	0.76^{f}	1.10^{a}
Average	0.62^{c}	1.20^{a}	1.24^{a}	0.80^{b}	

Note: Different superscripts in the same row or column show significant differences according to Duncan's Distance Test at the 5% level.
TM = without mulch; EFB = empty fruit bunches of oil palm; JP = rice straw; BJ = corn stover.

Regarding interaction, the highest K value was 1.62 me/100 g at 50 cm above ground level with rice straw mulch application, while the lowest was 0.56 me/100 g at 30 cm above ground level without mulch. Even though there were several treatments with very high yields, the element K decreased after the treatment was given. The maximum K value after treatment was below the K value in the initial soil sample, which was very high, namely 1.91 me/100 g. According to Maftu'ah et al. (2014), organic matter contains high nutrients which are easily decomposed and mineralized to release nutrients quickly, but the K released will also be easily leached. Element K in peat soil is a relatively fast leaching nutrient because there are no coordination bonds with peat functional groups.

Magnesium (Mg)

The variance test results showed that the treatment of various groundwater levels significantly affected Mg, while applying multiple types of organic mulch had no significant impact. The combination of the two treatments also showed no interaction. The results of Duncan's Advanced Test at the 5% level are presented in Table 9.

Table 9. Mg of soil at various groundwater levels and applications of different types of organic mulches (me/100 g)

Water Level	Organic Mulch				Mean
	TM	TKKS	JP	BJ	
30 cm	6.13	5.84	5.87	5.76	5.90^{a}
40 cm	5.43	5.20	5.74	5.55	5.48^{b}
50 cm	5.47	5.24	5.54	5.72	5.49^{b}
Average	5.68	5.43	5.71	5.67	

Note: Different superscripts in the same row or column show significant differences according to Duncan's Distance Test at the 5% level.
TM = without mulch; EFB = empty fruit bunches of oil palm; JP = rice straw; BJ = corn stover.

Table 8 shows the highest Mg, namely 5.90 me/100 g at TMA 30 cm, significantly different from other TMA. In general, the Mg content in the soil increased after being treated. The overall Mg value in each treatment unit is included in the high criteria, the same as the Mg value in the initial soil, which is 5.20 me/100 g. According to Hutagalung, et al. 2019), Mg can increase soil pH and benefit the development of soil structure. In addition, Mg is also an essential macro nutrient for plant growth.

Natrium (Na)

The variance test results indicated a significant interaction between the treatments of various groundwater levels and the application of various types of organic mulches to Na. Each of the two treatment factors also had a significant effect on Na. The results of Duncan's Advanced Test at the 5% level are presented in Table 10.

Table 10. Na at various groundwater levels and applications of different types of organic mulches (me/100 g)

Water Level	Organic Mulch				Mean
	TM	TKKS	JP	BJ	
30 cm	0.57^{cde}	0.50^{de}	0.67^{abc}	0.68^{abc}	0.60^{a}
40 cm	0.62^{bcd}	0.47^{e}	0.61^{bcd}	0.46^{e}	0.54^{b}
50 cm	0.52^{de}	0.55^{de}	0.70^{ab}	0.75^{a}	0.63^{a}
Average	0.57^{bc}	0.51^{c}	0.66^{a}	0.63^{ab}	

Note: Different superscripts in the same row or column show significant differences according to Duncan's Distance Test at the 5% level.
TM = without mulch; EFB = empty fruit bunches of oil palm; JP = rice straw; BJ = corn stover.

Table 9 shows an increase and decrease in the element of Na after the treatment compared to the initial soil, which was 0.65 me/100 g. By interaction, the highest Na was 0.75 me/100 g at 50 cm TMA with corn stover mulch application, while the lowest was 0.46 me/100 g at 40 cm TMA with corn stover mulch application. In general, the Na value is included in the medium criteria, except for the 50 cm TMA with corn stover application, which is included in the high criteria.

Hanafiah (2012) explained that like micro elements, Na can also be toxic if it is present in soil with high or excessive levels. One of the symptoms of Na toxicity in plants is stress due to high osmotic pressure. Therefore, the Na content at moderate levels as in this study is still good for plants to use.

4. CONCLUSION

Treatment of 30 cm TMA and rice straw mulch increased pH, Ca and Mg values better than other treatments, N element also increased at 30 cm TMA. In general, the two treatment factors also increased the values of P, CEC and Na in some experimental units. C-organic and K values decreased after the treatment compared to the soil criteria before treatment.

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