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Improving Effects of Different Calcium-Magnesium Conditioners on Latosol

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Abstract: At present, soil acidification seriously restricts the sustainable development of agricultural production. A common method that can be used to improve acidified soils is to apply calcareous materials (conditioners), but there is difference in the improvement effect of the conditioners on the same soil because of the conditioners containing different calcium-magnesium compounds. In order to find suitable conditioners for latosol (acidic red soil), two consecutive soil incubation experiments in laboratory have be done to study the improvement effects of different calcium-magnesium compounds on latosol. The results showed that: (1) Self-made conditioner (CM and it is composed of $Mg(OH)_2$, $Ca(OH)_2$, $MgCl_2$, $CaCl_2$,), CaO, $CaCO_3$ and $Mg(OH)_2$ could rapidly increase the pH and significantly reduce the content of potential acid in latosol. The soil exchangeable acid of $Mg(OH)_2$, $CaCO_3$, CaO and CM treatments than the treatment without conditioner (CK) were reduced by 88, 72, 66 and 34%, respectively, and the soil exchangeable aluminum decreased by 91, 80, 71 and 58%, respectively. (2) The calcium-magnesium compounds can significantly increase the contents of soluble and exchangeable calcium in soil compared with CK. CM and $Mg(OH)_2$ significantly increased the contents of soluble and exchangeable magnesium in latosol. (3) The soil pH buffer capacity of CM is significantly higher than those of other treatments as a result of it has the highest organic matter content and significantly increases the contents of exchangeable calcium and magnesium in the soil. But the soil pH buffer capacity of $CaCO_3$ and $Mg(OH)_2$ are significantly less than that of CK. Because the organic matter and organic acid of $CaCO_3$ and $Mg(OH)_2$ treatments are reduced by the soil pH of them increasing and the functional groups with pH buffer capacity on them may also be destroyed. So the paper suggests that improve acid latosol by applying conditioners with more soluble calcium and magnesium, $Mg(OH)_2$, which can effectively reduce acid ions in soil and improve the pH buffer capacity of soil.

Keywords: Latosol, Soil Conditioners, Exchangeable Ca and Mg, pH Buffer Capacity

Introduction

At present, the problem of soil acidification caused by factors such as climate, acid rain, long-term application of chemical fertilizer, etc., seriously restricts the sustainable development of agricultural production. According to statistics, acid soil accounts for 40% of the total area of cultivated land in the world (Teutscherova *et al*., 2017) and is 21% of the total cultivated land area in China and the acidified soil area is increasing. Soil acidification has become an issue of global agriculture (Guo *et al*., 2010). The main reason for soil acidification is that many base ions such as calcium and magnesium in the soil had leached loss, resulting in the release of acid ions such as hydrogen and aluminum ions. Soil acidification can lead to a series of problems such as soil nutrient imbalance, soil compaction and soil fertility decline, which are bad for crop growth and development (Lu *et al*., 2014).

At present, in the domestic and foreign research on soil acidity improvement, the commonly used method is to control the soil acidification by applying alkaline conditioners with calcium and magnesium (Antonangelo *et al*., 2017). The application of alkaline conditioners can effectively increase the pH of acidic soil in a short time and can neutralize the potential acid, reduce the exchangeable acid ion in acid soil, while supplement the calcium and magnesium in acidic soil. Commonly used calcareous materials that can be used to improve acidified soil are mainly alkaline materials with calcium and magnesium such as quicklime (CaO), slaked lime ($Ca(OH)_2$), limestone ($CaCO_3$), dolomite powder ($CaMg(CO_3)_2$), industrial and mining by-products (MgO, CaO, $Ca(OH)_2$, $Mg(OH)_2$, $CaCO_3$ and $MgCO_3$) (Lollato *et al*., 2013). The reason that all kinds of calcareous materials can improve acidic soil is mainly because it contains a large amount of calcium-magnesium alkaline compounds, but the acidity improvement effect on the same soil is different because of each material contains different calcium-magnesium compounds (Illera *et al*., 2004). Therefore, it is important to study the improvement effect of different alkaline calcium-magnesium compounds on acidic soils, which is essential for the production or selection of calcareous conditioners with high-quality calcium-magnesium compounds to improved acidified soil, which can effectively improve acidic soils and is of great significance to sustainable development of agricultural production at the same time.

In this study, the self-made calcium-magnesium conditioner, calcium oxide, calcium carbonate and magnesium hydroxide were used as research objects. The method of soil incubation in laboratory was used to study the improvement effect of different alkaline calcium-magnesium compounds on latosol in order to find the suitable calcareous conditioner for latosol and reduce soil acidity and provide a theoretical basis for the improvement and sustainable use of latosol.

Materials and Methods

Test Soil

The test soil was taken from ploughed soil with the thickness of 0-20 cm (21°9'15"N, 110°17'30"E) of sugar cane land in Waihuan West Road, Guangdong Ocean University, Zhanjiang City, Guangdong Province, China. The soil is a typical acid latosol derived from basalt in the Leizhou Peninsula. The soil samples were naturally air-dried, ground and sieved through 2 and 0.149 mm, respectively for soil incubation tests and for determination of basic physical and chemical values of soil. The basic physical and chemical properties of the tested soil (Initial soil) are as follows: pH 4.29, EC 0.71, total nitrogen 0.41 g/kg, available nitrogen 64.62 mg/kg, available phosphorus 17.48 mg/kg, available potassium 117.10 mg/kg, organic matter 21.12 g/kg, exchangeable calcium 3.25 cmol/kg, exchangeable magnesium 1.56 cmol/kg, soluble calcium 0.11 cmol/kg, soluble magnesium 0.21 cmol/kg, exchangeable acid 3.06 cmol/kg, exchangeable ammonium 2.40 cmol/kg, pH buffer capacity 33.86 mmol/kg.

Test Soil Conditioner

The self-made Calcium-Magnesium conditioner (CM) used in this study is a calcium-magnesium alkaline compound produced by seawater as raw material through resins and inputting lime precipitation method (Li *et al*., 2019). Its main component is $Mg(OH)_2$, $Ca(OH)_2$, $MgCl_2$, $CaCl_2$, other components and the percentage of the weight of each component is 12, 23, 3, 60 and 2%, respectively.

The test calcium oxide is an analytically pure CaO drug (AR), calcium carbonate is an analytically pure $CaCO_3$ drug (AR) and magnesium hydroxide is an analytically pure $Mg(OH)_2$ drug (AR). The basic physical and chemical properties of the test soil conditioners are shown in Table 1.

Experimental Design

The experimental site of this study is the third experimental building of Guangdong Ocean University, Zhanjiang, Guangdong, China, located at latitude of 21°8'N and a longitude of 110°17'E. The soil incubation method is adopted. The incubation time is from October 2018 to December 2018, from December 2018 to February 2019 for two consecutive experiments. Each incubation box was filled with 2kg of soil and the four types of soil conditioners were respectively placed in the incubation box with stirring well and total amount of pure calcium and magnesium in each conditioner added to the soil was calculated to correspond to 0.09% of the soil mass, that is, Calcium-Magnesium conditioner (CM), CaO, $CaCO_3$, $Mg(OH)_2$, four treatments were set and another blank control (CK) without added conditioner was set. Five treatments in total, three replicates per treatment, a total of 15 replicates.

Table 1: Basic physicochemical property of conditioners for testing

Conditioners	CM	CaO	$CaCO_3$	$Mg(OH)_2$
pH	11.15	12.15	8.54	10.23
EC (ms/cm)	172.35	55.50	8.44	3.80
Purity (%)	98.00	98.00	99.00	95.00
Soluble calcium (g/kg)	239.04	3.82	0.21	0.03
Soluble magnesium (g/kg)	7.67	0.01	0.01	0.42

Soil Samples Collection and Samples Analysis

Regularly added water and kept the soil water content at 70% of the field moisture capacity. After adding water, stirring well to make it uniform, putting it into the MGC-450 HP-2 artificial climate chamber, set the temperature to 26°C and incubated at the humidity of 60% for 56 days. Soil samples were taken on days 1, 2, 6, 12, 26, 41 and 56 of the incubation and 2 soil samples were taken from each box, that is, 6 replicate soil samples were taken for each treatment.

Soil pH was measured by laboratory pH meter (PHSJ-3F), soil EC value was measured by conductivity meter (DDSJ-308A conductivity meter), exchangeable acidity and ammonium (Al) were measured by potassium chloride-titration method (Bao, 2010), pH buffer capacity was measured by pH titration and buffering curve (Bao, 2010), soil exchangeable calcium and magnesium ions were measured by extracting with ammonium acetate-atomic absorption spectroscopy method (Hitachi, ZA3000, AAS) (Seeger *et al*., 2019), the soil organic carbon was measured by extracting soil samples with $K_2Cr_2O_7$ and H_2SO_4-titration with standardized $FeSO_4$ (Fu *et al*., 2010), total nitrogen was measured by the Kjeldahl method (Fu *et al*., 2010), available nitrogen in soil was determined by automated colorimetric methods after extraction with 2M KCl (Takeda *et al*., 2020), molybdenum-antimony colorimetry (UV-1100 ultraviolet spectrophotometer) for the measurement of available phosphorus (Bao, 2010), ammonium acetate-flame photometric method (FP6431 flame photometer) for the measurement of available potassium (Bao, 2010).

Data Statistical Analysis Method

Each experiment consisted of three replicates (six replicate samples) per treatment. Data were analyzed as means of two consecutive experiments (October 2018-December 2018, December 2018-February 2019) and the differences among treatments were computed using Duncan's multiple range test at p = 0.05. All data analysis and statistics were performed using SPSS18.0 and Microsoft Excel 2010.

Results and Discussion

Effects of Different Calcium-Magnesium Conditioners on the pH of Soil

It can be seen from the results in Fig. 1 that the soil pH values of the four calcium-magnesium conditioners were much higher than those of CK treatment and the difference between treatments was significant. The soil pH order of each treatment was $Mg(OH)_2$ > $CaCO_3$ > CaO > CM > CK. It can also be seen from Fig. 1 that during the 56-day incubation period, the soil pH of CK and the pH of the initial soil (4.29) are basically the same and the change is not obvious and the pH of added four calcium-magnesium conditioners rose rapidly at the first day and then stabilized. This indicates that the application of CM, CaO, $CaCO_3$, $Mg(OH)_2$ can rapidly increase the pH of the acidic soil, especially the $Mg(OH)_2$ treatment and the soil pH is increased by more than one unit during the whole incubation period. This may be because the different calcium-magnesium compounds are alkaline materials and the OH^- formed after added it to the soil neutralizes the active acid H^+ in the soil solution, so the pH is increased. Probably because $Mg(OH)_2$ contains OH^-, OH^- itself, which can react directly with active acid in the soil, so $Mg(OH)_2$ has the most significant effect on increasing the pH of soil.

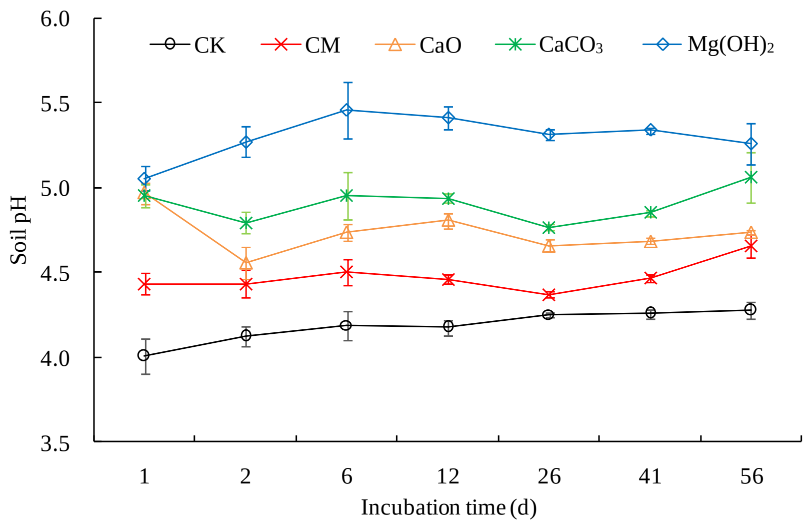

Fig. 1: Effects of different conditioners on soil pH

Effects of Different Calcium-Magnesium Conditioners on Soil Exchangeable Acid and Exchangeable Aluminum

In acidic mineral soils, the active acid (soil pH) is mainly derived from soil potential acids, i.e., soil exchangeable acid ions (H^+ and Al^{3+}). Generally soil pH is negatively related to soil exchangeable acidity (H^+ and Al^{3+}). Especially three units H^+ are produced after one unit Al^{3+} hydrolysis ($Al^{3+} + 3H_2O = Al(OH)_3 + 3H^+$), which is the main cause of low pH in acidified soil and activity of Al^{3+} is strong and plants are easily affected by aluminum toxicity (Elisa *et al*., 2015). Therefore, the study of exchangeable acidity and exchangeable Al^{3+} in soil is an important reference indicator for determining improvement effects of acid soil with the conditioners.

As shown in Fig. 2, the soil exchangeable acidity without adding soil conditioner (CK) remained substantially above 3 cmol/kg throughout the incubation period and the exchangeable acidity increased with the prolongation of the incubation time. When the soil conditioners was applied, the content of soil exchangeable acid decreased and those of $Mg(OH)_2$, $CaCO_3$, CaO and CM treatments was decreased by 88, 72, 66 and 34% compared with CK treatment, respectively. During the whole incubation period, the difference of exchangeable acidity between treatments was significant. The soil exchangeable acidity of $Mg(OH)_2$ treatment was stable below 0.5 cmol/kg, which was the most effective one of reducing soil potential acid in four calcium-magnesium conditioners.

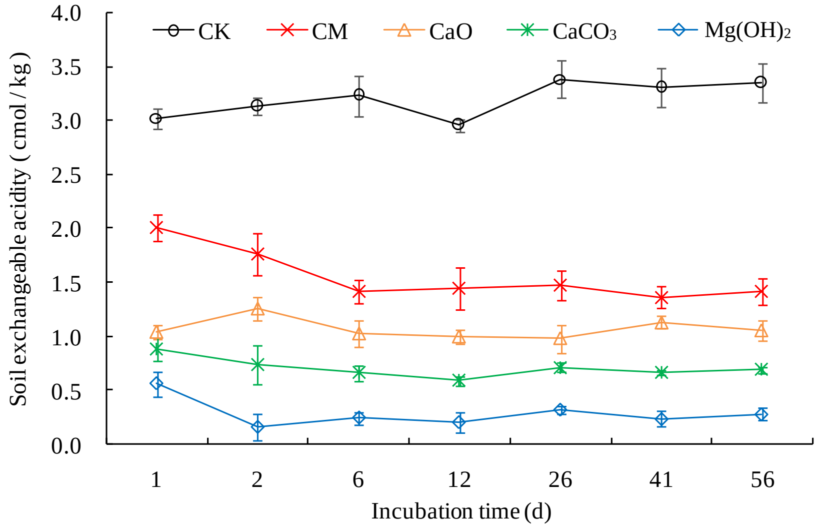

Fig. 2: Effects of different conditioners on soil exchangeable acid

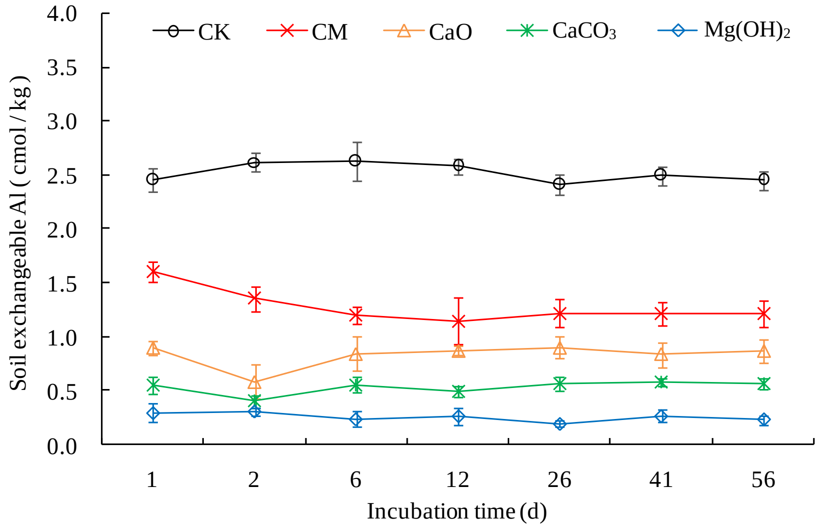

Fig. 3: Effects of different conditioners on soil exchangeable aluminum

It can be seen from Fig. 3 that the application of calcium-magnesium conditioners can significantly reduce the content of soil exchangeable aluminum and alleviate the aluminum toxicity of acid soil to crops. In 56 days, the average content of soil exchangeable aluminum treated by CM, CaO, $CaCO_3$ and $Mg(OH)_2$ was 58, 71, 80 and 91% lower than that of CK, respectively. The exchangeable aluminum content between the four conditioners is significantly different and the effect of reducing the exchangeable aluminum content is: $Mg(OH)_2 > CaCO_3 > CaO > CM$.

In summary, the calcium-magnesium conditioners can effectively reduce acid ions in acidic soils, thus reducing the adverse effects of soil acidification on crop growth. That was mainly because the alkaline component in the calcium-magnesium conditioner neutralizes the potential acid in the soil and supplements the calcium ions and magnesium ions that are lacking in the acidic soil. Considerable calcium and magnesium ions are absorbed by the soil colloid, replacing the original potential acid adsorbed in soil colloid, which can effectively reduce the content of soil exchangeable acid and exchangeable aluminum (Zhang *et al*., 2011). Considering the reduction of soil potential acid and active acid, $Mg(OH)_2$ has a better effect on improving acid latosol. The possible reason is that $Mg(OH)_2$ contains the most alkaline OH^+. Once applied to the soil, it can directly neutralize the acid ions in the soil, while other calcium-magnesium conditioners contain less OH^+ that may need to react with water in the soil to produce OH^+ to neutralize acid ions.

Effects of Different Calcium-Magnesium Conditioners on Soil Organic Matter

Soil organic matter is an important source of various nutrients in the soil. It can also increase the pH buffer capacity of the soil and affect the pH of soil. Otherwise, the pH can also affect the soil organic matter content (Curtin and Trolove, 2013). As shown in Table 2, after 56 days of incubation, the soil organic matter content of the other treatments decreased comparing with that of the initial soil (21.12 g/kg) except for the CM treatment. This indicates that soil organic matter is mineralizing decomposed during soil incubation, so the content will be reduced. There is a difference in the degree of organic matter reduction between treatments. The more soil pH is increased, the less soil organic matter is decreased except for the CM, which are $Mg(OH)_2 < CaCO_3 < CaO$ and CK. This may be because when the soil pH is between 6.5 and 7.5, it is suitable for the growth of most soil microorganisms and is beneficial to the mineralizing decomposition of organic matter (Curtin *et al*., 1998). When the pH of the strongly acidic soil increases, it is beneficial for the microorganism to decompose the organic matter. The results in Table 2 also show that the organic matter content of CM is the highest and there is almost no change comparing with the initial soil. This may be because soil with CM treating contains more soluble calcium and magnesium and high salinity inhibits the decomposition of soil organic matter by microorganisms.

Effects of Different Calcium-Magnesium Conditioners on Soil EC and Water-Soluble Calcium and Magnesium

Soil EC refers to the total amount of water-soluble salts contained in the soil. As can be seen from Fig. 4, the four calcium-magnesium conditioners significantly increased the EC of the soil compared to the CK treatment and the soil EC treated by CM was significantly higher than that of the other calcium-magnesium conditioners. This is because CM contains more water-soluble calcium and magnesium, such as $MgCl_2$ and $CaCl_2$ and when it is put into the soil, it can significantly increase the total amount of water-soluble salts in the soil.

As can be seen from Table 3, the difference in soil water-soluble calcium and magnesium contents between treatments was significant ($p<0.05$). Compared with other treatments, CM treatment can significantly increase the content of soluble calcium and magnesium in soil, which is mainly related to the fact that CM contains more soluble calcium and magnesium ions. Compared with the CK control, CaO and $CaCO_3$ treatment can significantly increase the content of soluble calcium, which is mainly because they contain more calcium ions and when it is put into the soil, some calcium ions are dissolved in the soil aqueous solution. $Mg(OH)_2$ treatment can significantly increase the soluble magnesium content, which is related to the fact that $Mg(OH)_2$ contains more magnesium ions.

Effects of Different Calcium-Magnesium Conditioners on Soil Exchangeable Calcium and Magnesium

Exchangeable calcium and magnesium ions are important base cations in the soil. Generally, the higher the base saturation, the lower the acid ion content in the soil and the higher the pH of soil. At the same time, exchangeable cations, such as exchangeable calcium and magnesium, are also closely related to the pH buffer capacity of the soil (Zhang *et al*., 2013). Therefore, it is of great significance to study the effects of calcium-magnesium conditioners on the exchangeable calcium and magnesium content of soil and its effect on improving acid soil. From the average of the treatments on days 26 and 56 (Table 4), the application of the four calcium-magnesium conditioners significantly increased the soil exchangeable calcium content compared to CK. Among them, CM and $CaCO_3$ treatment increased more exchangeable calcium, followed by CaO and $Mg(OH)_2$

treatment. The mean exchangeable calcium of CM, $CaCO_3$, CaO and $Mg(OH)_2$ was increased by 87, 85, 58 and 20%, respectively compared to the mean exchangeable calcium of CK. The four calcium-magnesium conditioners can increase the exchangeable calcium content to different extents, which is mainly related to the calcium ions with different forms and contents. The exchangeable calcium content of CM, $CaCO_3$, CaO treatments were higher than those of $Mg(OH)_2$ and CK showed that the conditioners with more calcium ions can increase more soil exchangeable calcium. The higher exchangeable calcium content in soil with CM treating compared to other calcium-containing conditioners shows that the more conditioners contain available calcium (60% $CaCl_2$), the more soil exchangeable calcium is increased.

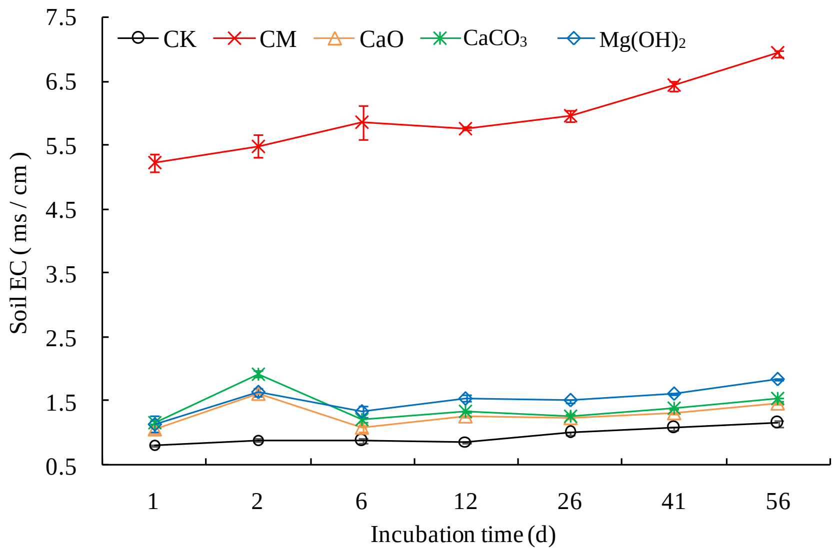

Fig. 4: Effects of different conditioners on soil EC

Table 2: Effects of different conditioners on soil organic matter (g/kg)

Treatments	CK	CM	CaO	$CaCO_3$	$Mg(OH)_2$
Organic matter	19.24±0.78b	20.63±0.00a	19.78±0.75ab	18.41±0.36bc	17.82±0.97c

Note: The values are means ± standard deviation, the data were analyzed as means of two consecutive experiments (n = 12). Different small letters in the same line meant significant differences among conditioner treatments (P<0.05)

Table 3: Effects of different conditioners on soluble Ca and Mg (cmol/kg)

Time	Content	CK	CM	CaO	$CaCO_3$	$Mg(OH)_2$
26 (d)	Ca	0.15±0.02d	1.30±0.07a	0.32±0.05b	0.35±0.02b	0.20±0.15c
	Mg	0.20±0.04c	1.58±0.07a	0.10±0.01d	0.10±0.03d	0.45±0.03b
56 (d)	Ca	0.18±0.02e	1.29±0.05a	0.35±0.03c	0.41±0.03b	0.26±0.02d
	Mg	0.13±0.02c	1.44±0.11a	0.11±0.01c	0.11±0.02c	0.53±0.02b
Mean	Ca	0.18±0.05e	1.30±0.06a	0.33±0.04c	0.38±0.04b	0.23±0.03d
	Mg	0.18±0.05c	1.51±0.12a	0.10±0.01d	0.10±0.02d	0.48±0.04b

Note: The values are means ± standard deviation, the data were analyzed as means of two consecutive experiments (n = 12). Different small letters in the same line meant significant differences among conditioner treatments (P<0.05)

Table 4: Effects of different conditioners on exchangeable Ca and Mg (cmol/kg)

Time	Content	CK	CM	CaO	$CaCO_3$	$Mg(OH)_2$
26 (d)	Ca	3.29±0.22e	6.56±0.26a	5.90±0.00c	6.29±0.19b	4.22±0.09d
	Mg	1.61±0.00d	3.96±0.34b	2.16±0.14c	1.85±0.27d	5.29±0.37a
56 (d)	Ca	3.22±0.14d	5.81±0.14a	4.52±0.34b	5.86±0.09a	3.75±0.00c
	Mg	2.02±0.41b	5.29±0.58a	2.90±0.46b	2.13±0.31bc	5.70±0.49a
Mean	Ca	3.26±0.22d	6.18±0.44a	5.21±0.75b	6.08±0.26a	3.96±0.24c
	Mg	1.82±0.59c	4.61±0.84b	2.50±0.49c	1.99±0.31c	5.48±0.46a

Note: The values are means ± standard deviation, the data were analyzed as means of two consecutive experiments (n = 12). Different small letters in the same line meant significant differences among conditioner treatments (P<0.05)

Table 5: Effects of different conditioners on soil pH buffer capacity

	pH buffer capacity (mmol/kg)				
Time (d)	CK	CM	CaO	$CaCO_3$	$Mg(OH)_2$
6	33.6±1.44b	36.4±0.00a	31.2±0.69c	30.8±0.20c	29.9±0.39c
12	31.5±0.35d	35.9±0.45a	30.6±0.19e	32.3±0.21c	33.6±0.32b
26	32.7±0.30a	31.2±0.27b	32.7±0.30a	28.0±0.33d	28.8±0.06c
41	30.9±0.00b	33.3±0.00a	30.7±0.14b	29.9±0.41c	28.1±0.62d
56	30.5±0.16b	32.2±0.29a	28.6±0.46d	28.1±0.09d	29.7±0.25c
Mean	31.6±1.00b	33.9±2.06a	30.6±1.31bc	29.8±1.68c	29.8±1.91c

Note: The values are means ± standard deviation, the data were analyzed as means of two consecutive experiments (n = 12). Different small letters in the same line meant significant differences among conditioner treatments ($P<0.05$)

The results in Table 4 also show that CM and $Mg(OH)_2$ significantly increase soil exchangeable magnesium content compared to CK, while $CaCO_3$ and CaO treatments are not significantly different from CK. Among them, $Mg(OH)_2$ treatment increased the most exchangeable magnesium, followed by CM, which is mainly because $Mg(OH)_2$ contained the most magnesium ions, followed by CM. When it was put into the soil, magnesium-containing conditioner can gradually release magnesium ions, which are absorbed by the soil colloid. It can be seen from the fact that the exchangeable magnesium content of day 56 is more than that of day 26.

Effects of Different Calcium-Magnesium Conditioners on Soil pH Buffer Capacity

The degree of soil acidification is related to soil pH, acid ion input and buffer capacity of soil to acid. Among them, soil pH buffer capacity is the ability of soil to reduce soil acidification in response to external factors and soil pH buffer capacity can predict soil acidification process and its trend. The larger the pH buffer capacity is, the stronger soil buffer capacity for external acidity and the more stable pH in soil will be. The stable soil pH is conducive to the absorption and utilization of soil nutrient elements by plants and the maintenance of soil ecological functions (Augusto *et al*., 2017).

From the results of the average pH buffer capacity of each treatment within 56 days (Table 5), CM was significantly greater than other treatments and the soil buffer capacity was increased by 2.37 mmol/kg compared to CK treatment. The soil buffer capacity of CaO, $CaCO_3$ and $Mg(OH)_2$ was decreased by 0.98, 1.72 and 1.73 mmol/kg, respectively compared to CK treatment and the buffer capacities of $CaCO_3$ and $Mg(OH)_2$ were significantly lower than that of CK. This is mainly because the pH buffer capacity of soil is closely related to its pH buffer system and soil exchangeable cation, organic acid and organic matter are important parts of the soil acid-base buffer system (Nguyen, 2018). When CaO, $CaCO_3$ and $Mg(OH)_2$ are added to the acidic soil, the alkaline component of the conditioner neutralizes the acidic materials in the soil, including low molecular organic acids in the soil. At the same time, the increase of pH promotes decomposition of soil organic matter (Table 2). The organic matter and organic acid are reduced and the functional groups with pH buffer capacity on them may also be destroyed, such as hydroxyl, carboxyl, phenolic hydroxyl group, alcoholic hydroxyl group (Curtin and Trolove, 2013). Therefore, the reduction of organic matter content and the destruction of functional groups on organic matter are the main reasons for the decrease of soil pH buffer capacity of CaO, $CaCO_3$ and $Mg(OH)_2$ treatments. Although the pH of soil treated by CM is also increased, it has the lowest pH increase compared with other calcium-magnesium conditioners (Fig. 1), the highest organic matter content (Table 2) and significantly increased the contents of exchangeable calcium and magnesium in the soil (Table 4), i.e., exchangeable cation is supplemented. Therefore, CM can effectively improve the pH buffer capacity of the acid latosol.

It can be seen from Table 5 that with the prolongation of incubation time, the soil pH buffer capacity of each treatment has a different degree of decline, which may be related to the decrease of organic matter and organic acid and functional groups with pH buffer capacity were destructed led by organic matter decomposition during soil incubation.

Conclusion

Applications of CM, CaO, $CaCO_3$ and $Mg(OH)_2$ could rapidly increase the pH of acid latosol and significantly reduce the potential acid content in soil. During the whole incubation period, the soil pH of $Mg(OH)_2$ was increased by more than one unit compared with CK treatment. The soil exchangeable acid of $Mg(OH)_2$, $CaCO_3$, CaO and CM was reduced by 88% and 72, 66 and 34% comparing to CK treatment, respectively. The soil exchangeable aluminum decreased by 91, 80, 71 and 58%, respectively. Among them, $Mg(OH)_2$ has the best effect on reducing active acid and potential acid in latosol.

The application of these four calcium-magnesium conditioners can significantly increase the content of soluble and exchangeable calcium in soil compared with CK treatment. The average exchangeable calcium of CM,

$CaCO_3$, CaO and $Mg(OH)_2$ was increased by 87, 85, 58 and 20%, respectively. Application of CM and $Mg(OH)_2$ significantly increased soil soluble and exchangeable magnesium content, while $CaCO_3$ and CaO treatments' effects on exchangeable magnesium were not significantly different from CK treatments and Mg(OH)2 treatment increased the most exchangeable magnesium among them.

The soil pH buffer capacity of CM is significantly higher than that of other treatments, which has the best effect on improving the pH buffer capacity of latosol, while the soil pH buffer capacity of $CaCO_3$ and $Mg(OH)_2$ are significantly less than that of CK. CaO and CK have no significant differences.

Therefore, this paper proposes to improve the acid latosol by applying calcareous conditioner with more water-soluble calcium and magnesium ions and magnesium hydroxide, which can effectively reduce the acid ion content in the soil and improve the pH buffer capacity of the soil. But the paper did not involve the optimal percentage of the weight of each component ($Mg(OH)_2$, $Ca(OH)_2$, $MgCl_2$, $CaCl_2$,) in CM, which is the research field in the future.

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Author’s Contributions

Jin Li and Yingbin Xue: Designed and performed the experiments, analyzed the data and prepared the paper. Both authors contributed equally to this work.

Minzhong Chen: Participated to collect the materials related to the experiment.

Huirong Su and Zhengwei Wu: Collection and assembly of data, data analysis and interpretation.

Tingting Duan: Research concept and design, final approval of article.

Ethics

Authors should address any ethical issues that may arise after the publication of this manuscript.

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