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Acidity Control After Surface Application of Micronized Liming Material in a Typic Distrudept Under No-Tillage

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HIGHLIGHTS

- The fineness particles of micronized liming do not favor the soil reaction in the 5-60 cm layer.
- The micronized liming increase pH values in the 0-5 cm layer, in an Inceptisol under no-tillage.
- The gap between the soil base saturation estimated and obtained is smaller with micronized liming.
- The liming materials not changed chemical attributes below the point of placement, in an Inceptisol.

Abstract: The objected to evaluate the pH and soil base saturation (V) values, during 45 months after, surface application and without incorporation of the liming materials in deeper layers of soil. The experimental design was completely randomized blocks in split-plot with four replications. In the plots were studied the dolomitic limestone (DL) and micronized liming materials (MLM) – granulated micronized calcite (GMC) and dolomite (GMD), and carbonated suspension (CS). In the subplots were studied doses of all the liming materials aiming to increase V to 50, 70 and 90% besides of control treatment. We measured the pH and V values in 0-5, 5-10, 10-20, 20-40 and 40-60 cm soil layers over time (5, 15, 28, 37 and 45 months). The MLM were more efficient to increase and maintain the pH and V, over time, than DL. The doses of MLM aiming V to 50-70% increasing the pH and V of Typic Distrudept. Despite the MLM are more fineness than DL, the effectiveness for soil acidity control in subsoil were inefficient, because theses pH and V increases/maintains occurred just in 0-5 cm layer. However, the MLM present lower gap between the V estimated and obtained, in the 0-5 cm layer, than DL.

Keywords: soil reaction, soil with variable charge, soil base saturation, pelletized limes, fluid lime.

INTRODUCTION

Around 40% of the land used for agriculture in the world have their productivity limited by soil acidity [25]. The acidification occurs due to following factors: rainfall higher; basic cations displaced by H⁺; basic cations leached; use of nitrogen (N) fertilizer and/or N fixation [12]; oxides-Al and oxides-Fe accumulation; higher aluminum (Al) and manganese (Mn) concentration; release of H⁺ from soil organic; Al and Fe hydrolysis; uptake of cations favoring extrusion of H⁺ [13,14]; and acidity deposition by fossil fuel combustion [16].

Therefore, the soil acidity control is important for keeping of crop yield and reduce of soil fertility loss, mainly in variable charge soils (as Typic Distrudept).

In no-tillage (NT), the soil acidity control occurs with surface application of liming materials, without incorporation. Then, the reaction of the liming material in NT is lower and gradual [5], but can resulting, along the time in amelioration of the soil fertility below the point of placement [18]. The liming materials provide ideals conditions of change in the pH and exchange complex, favoring the crops yield and amelioration of soils attributes [4, 6]. Besides, in soils with controlled acidity there is increase of crops yield due to carbon input [20] and this influence the soil reaction [13,14].

The liming materials more common employed for soil acidity control include calcite (CaCO_3), dolomite ($\text{Ca,Mg}(\text{CO}_3)_2$) and magnesite (MgCO_3) [4]. However, the common liming materials, as dolomitic limestone (DL), not presented faster dissolution than micronized liming material (MLM). These MLM can to control faster acidity and to be source of calcium and magnesium o soil-plant system [10, 11]. The major characteristics of MLM are faster reaction (< 30 days) and fineness (of 1.91 to 6.58 μm) [19, 10, 11]. The MLM can present themselves as particles pelletized, as the granulated micronized calcite (GMC) and granulated micronized dolomite (GMD), or in suspension with water (fluid), as the carbonated suspension (CS) [12, 10, 11].

Therefore, the understanding of the MLM effects application on soils with variable charge, as Inceptisol, will allow the development of rational strategies for acidity control. We hypotheses that, in soils with high buffering power and variable charge, the MLM applied in the surface and without incorporation can be more efficient than DL concern to increase and keep pH and base saturation (V) values below the point of placement. The objective of this study was to evaluate the pH and V values along of the 45 months as a result from surface application (without incorporation) of liming materials in the soil profile under NT.

MATERIAL AND METHODS

The trial experiment was carried out in a Typic Distrudept (Inceptisol), in Palmeira, Paraná, Brazil, during Jun/2012 to Mar/2016. The local weather is Cfb (humid subtropical climate), according to Köppen-Geiger classification and the accumulate rainfall during experimental period (2012 to 2016) was of 6524.8 mm. This area was managed under NT the last 15 years for soybean (grain production) and black oat (cover crop) during, respectively, the summer and winter season. At the beginning of the experiment in the 0-20 cm layer showed the following attributes [21]: pH (CaCl_2 0.01 mL.L^{-1} – 1:2.5) of 4.3, cation exchangeable capacity (CEC) of 145.6 $\text{mmol}_c \text{ dm}^{-3}$, V of 29.0%, organic carbon (C) of 21.0 g dm^{-3} , 1.24; 200.0 and 255.2 g kg^{-1} of the clay, silt and sandy, and 544.8 g dm^{-3} of bulk density. The pH and V values of the layers 0-5, 5-10, 10-20, 20-40 and 40-60 cm are being presented in the results as zero time. The CEC values of the layers 0-5, 5-10, 10-20, 20-40 and 40-60 cm is of 145,8; 149,3; 143,6; 129,5 and 124,5 $\text{mmol}_c \text{ dm}^{-3}$, respectively. And, the C values of the layers 0-5, 5-10, 10-20, 20-40 and 40-60 cm is of 28,0; 21,0; 17,5; 18,0 and 15,0 g dm^{-3} , respectively.

The experimental design employed was the randomized complete block in split-plot with four replications. In the plots (384 m^2) were studied the dolomitic limestone (DL) and three micronized liming material (MLM) – granulated micronized calcite (GMC), granulated micronized dolomite (GMD) and carbonated suspension (CS). In the subplots (96 m^2) the treatments were the control (V = 0%) plus three doses of liming material aiming to increase the V to 50, 70 and 90%. The liming requirement was performed by the method of elevation of soil base saturation. The doses are V estimated. The liming materials were applied in total area, on the soil surface, without incorporation, once in jun/2012.

The effective calcium carbonate equivalent (ECC) of DL, GMC, GMD and CS was of 952.0, 962.7, 1006.5 and 770.0 g kg^{-1} , respectively. The fineness factor (FF) value adopted for the MLM was of 1000 g kg^{-1} and for the DL was of 942.8 g kg^{-1} [10]. The GMC and GMD were pelletized lime, the CS was fluid lime (density is 1.89 kg dm^{-3}) and DL is powder lime (Figure 1). The doses aiming to increase of V to 50, 70 and 90 % was obtained through of the equations was suggested by current methodology [7]. The doses applied of DL were 3.22, 6.28 and 9.34 Mg ha^{-1} to increase of V to 50, 70 and 90%, respectively; of GMC were 3.18, 6.21 and 9.23 Mg ha^{-1} to increase of V to 50, 70 and 90%, respectively; of GMD were 3.05, 5.94 and 8.83 Mg ha^{-1} to increase of V to 50, 70 and 90%, respectively; of CS were 3.98, 7.76 and 11.54 Mg ha^{-1} to increase of V to 50, 70 and 90%, respectively.

After the liming material applications were the experimental area was cropped with wheat (2012 and 2014), soybean (2012/13 and 2014/15), black oat (2013 and 2015) and maize (2013/14 and 2015/16). During the experimental period (Jun/2012 to Mar/2016), no liming material was applied, and the accumulate rainfall was 6524.8 mm.

The nutrients inputs via fertilizers during the experimental period were 686, 700 and 538 kg ha^{-1} of N (as urea or as monoammonium phosphate), P_2O_5 (as single or triple superphosphate, or monoammonium

phosphate) and K_2O (as potassium chloride), respectively. The common agronomic practices used regionally for adequate crops development were employed.

The aleatory soil samples from 0-5, 5-10, 10-20, 20-40 and 40-60 cm were sampled by auger and dutch auger. Twelve simple samples were collected for performed a composite sample, in each layer of the subplot. The soil was sampled in 0 (at the beginning of the experiment), 5 (after the harvest of wheat 2012), 15 (after the harvest of soybean 2012/13), 28 (after the harvest of maize 2013/14), 37 (after the harvest of soybean 2014/15) and 45 (after the harvest of maize 2015/16) months after surface application of liming materials.

These samples were taken to the laboratory, dried in an oven at 40°C with forced air circulation over a period of 48 hours, ground and sieved in a 2.0 mm mesh sieve. Afterwards, pH, exchangeable-Ca, Mg and K values was performed according to regional methods [21]. The pH value was determined in a 0.01 mol L⁻¹ CaCl₂ solution using a 1:2.5 (v:v) soil-to-solution ratio suspension and after was determined H+Al with buffer solution SMP. The exchangeable-Ca and Mg values were determined in a 1.0 mol L⁻¹ potassium chloride (KCl) solution and titration using a standard 0.025 mol L⁻¹ EDTA (Ethylenediaminetetraacetic acid). The exchangeable-K value was determined in Mehlich-1 (0.05 mol L⁻¹ chloride acid (HCl) and 0.0125 mol L⁻¹ sulfuric acid (H₂SO₄)) solution. The V was calculated by the relationship between the Ca, Mg and K-exchangeable values sum and cation exchange capacity (in pH = 7.0) [12].

Statistical analysis was performed used the computer program SAS Version 9.1.2 [23]. The variance analysis was carried out using the PROC GLM command and Tukey test ($p < 0.05$) to averages the liming materials (DL, GMC, GMD and CS). The analysis of regression was carried out using the PROC REG command to adjust the dose (to increase V to 50, 70 and 90% besides to the control treatment) of each liming material and least significant difference (LSD) to compare the liming materials. The analysis of profile was carried out using the PROC GLM and REPEATED command procedures to measure the effects of doses and liming materials over time (0, 5, 15, 28, 37 and 45 months).

RESULTS

(Table 1) There were interactions between liming materials, doses and periods after application for pH and V values. (Figure 2) In the control treatment there was increase of the pH, in the all layers, along the time. However, the application of liming materials resulted in the pH changes just in the 0-5 cm layer than in others layers. In the 0-5 cm layer, all the doses of liming materials increased and remained the pH along the time, when compared with the control treatment.

(Figure 2) In the 0-5 cm layer, the pH increased and remained as from 28 months after application of DL in the dose V to 50 %. Being that, after 45 months, the pH measured was of 5.7 (the biggest pH for DL). Already for MLM, the pH increased and remained as from 5 months of application in the dose V to 50 %. Whereas the highest pH was observed, in the 0-5 cm layer, 28 months after the application of MLM in the dose V to 50 %. These pH values were of 6.2, 5.6 and 6.1 to GMC, GMD and CS, respectively. Already, the pH, after 45 months, were of 5.0, 5.4 and 5.5 to GMC, GMD and CS, respectively.

(Figure 2) The pH increased and remained during 5 up to 34 months of liming materials application in the dose V to 70 % and in the 0-5 cm layer. However, the major increased in the pH were observed for GMC, GMD and CS than for DL. Already, the highest pH observed was 23 and 11 months after application of DL (pH = 6.0) and GMC (pH = 6.4), respectively. And, the pH, after 45 months, were of 5.0 and 4.8 to DL and GMC, respectively. The highest pH was observed after 5 months of GMD and CS application and were of 6.1 and 6.7, respectively, both in the dose V to 70 %. After 45 months, the pH was of 5.4 and 5.5 to DL and GMC, respectively.

(Figure 2) Yet, in the 0-5 cm layer, the pH was increased and remained as from 5 months of MLM application in the dose V to 90%. And, the increased in the pH were observed in the following order GMC < GMD < CS < DL. Yet after 5 months, the highest pH values were of 5.7, 6.9, 6.5 and 6.9 to DL, GMC, GMD and CS, respectively. Already, after 45 months of DL, GMC, GMD and CS application in the dose to 90 %, the pH was of 5.5, 5.9, 5.1 and 5.5, respectively.

(Figure 3) The V in control treatment and in the all layers was increased along the time. However, after the application of liming material doses, the more variations in the V occurred in the 0-5 cm layer than 5-60 cm layer. In the 0-5 cm layer, the V increased and remained of 23 up to 45 months of DL application in the dose to 50 %. Besides, the V obtained after 45 months after application of DL was of 44 % more than V estimated. Yet, in the 0-5 cm layer, the V increased and remained as from 5 months after application of MLM in the dose to 50 %. Being that, the highest V in the dose to 50 % was observed 28 months after application of GMC (V obtained was 58 % more than V estimated) and after 34 months of GMD and CS application (V

obtained was of 38 and 52 % more than V estimated, respectively). Already, the V obtained, after 45 months, by GMC was 42 % and by GMD and CS was 30 % more than the V estimated 50 %.

(Figure 3) The V, in the 0-5 cm layer, increased and remained of 5 up to 34 months after application of DL and GMC in the dose V to 70%. Already, the highest V obtained was observed 28 months after the application of DL and GMC in the order of 2 and 14 % more than V estimated, respectively. Besides, the V obtained, after 45 months and in the 0-5 cm layer, by DL and GMC, for both, it was reached 82 % of the V estimated. And, the only treatment that the V obtained equal the estimated of 70 %, was the GMC after 34 months. Still in the 0-5 cm layer, the V increased and remained as from 5 months of GMD and CS application in the dose V to 70 %. The highest V obtained was observed 23 and 34 months after application of GMD and CS, in the order of 14 % more than V estimated, for both. Already, the V obtained, after 45 months, by GMD and CS, was reached 97 % of the V estimated of 70 %. (Figure 3) The V, in the 0-5 cm layer, increased and remained as from 5 months after application of all liming materials in the dose V to 90 %. The highest V obtained, was observed 34 months of DL and GMD application, both reached 88 % of V estimated. Already, the V obtained, after 45 months, by DL and GMD reached 73 and 65 % of V estimated, respectively. Besides, the highest V was observed 28 months after application of GMC and CS, both reached 93 % of V estimated. Already, the V obtained, after 45 months and in the 0-5 cm layer, by GMC and CS, both reached 82 % of the V estimated of 90 %.

(Figure 4) The pH was more influenced by doses of liming material in the 0-5 cm layer. The linear increases the pH was observed of 5 up to 34 months of application of liming materials, except for 28 months. Thus, the higher pH was observed in the dose V to 90 % after 5 months of DL and GMC application; after 11 months of all liming materials application, after 28 months of GMC, GMD and CS application; and after 34 months of DL and GMC application. The increase pH occurred 28 months after application of DL in the doses V to 50-70 %.

(Figure 5) The V was influenced by doses of liming material up to 20 cm depth than 20-60 cm. In the 0-5 cm layer, higher V was observed in the dose V to 90 % after 5, 23, 34 and 45 months of DL, GMD, GMC and CS application, respectively. In the 0-5 cm layer and in the dose V to 50-70 %, higher V was observed after 5 months of GMC, GMD and CS application; after 11 months of all liming material application; after 28 months of DL, GMC and CS application; after 34 months of CS application; and after 45 months of GMD application. Already, in the 5-10 cm layer, higher V was observed in the dose V to 50-70 % after 5 and 28 months of DL application. And, in the 10-20 cm layer, higher V was observed in the dose V to 50-70 % after 11 months of CS application. Besides, after 5 months of GMC application, in the 10-20 cm layer, higher V value was observed in the dose V to 90%.

Figures, Tables and Schemes

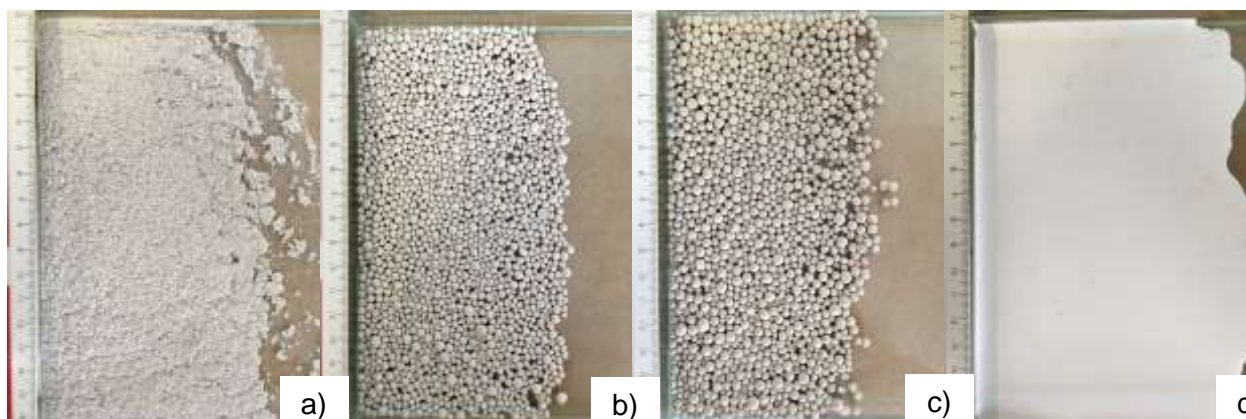


Figure 1. Granules size (cm) and arrangement of dolomitic limestone (DL) (a), granulated micronized calcite (GMC) (b), granulated micronized dolomite (GMD) (c) and carbonated suspension (CS) (d).

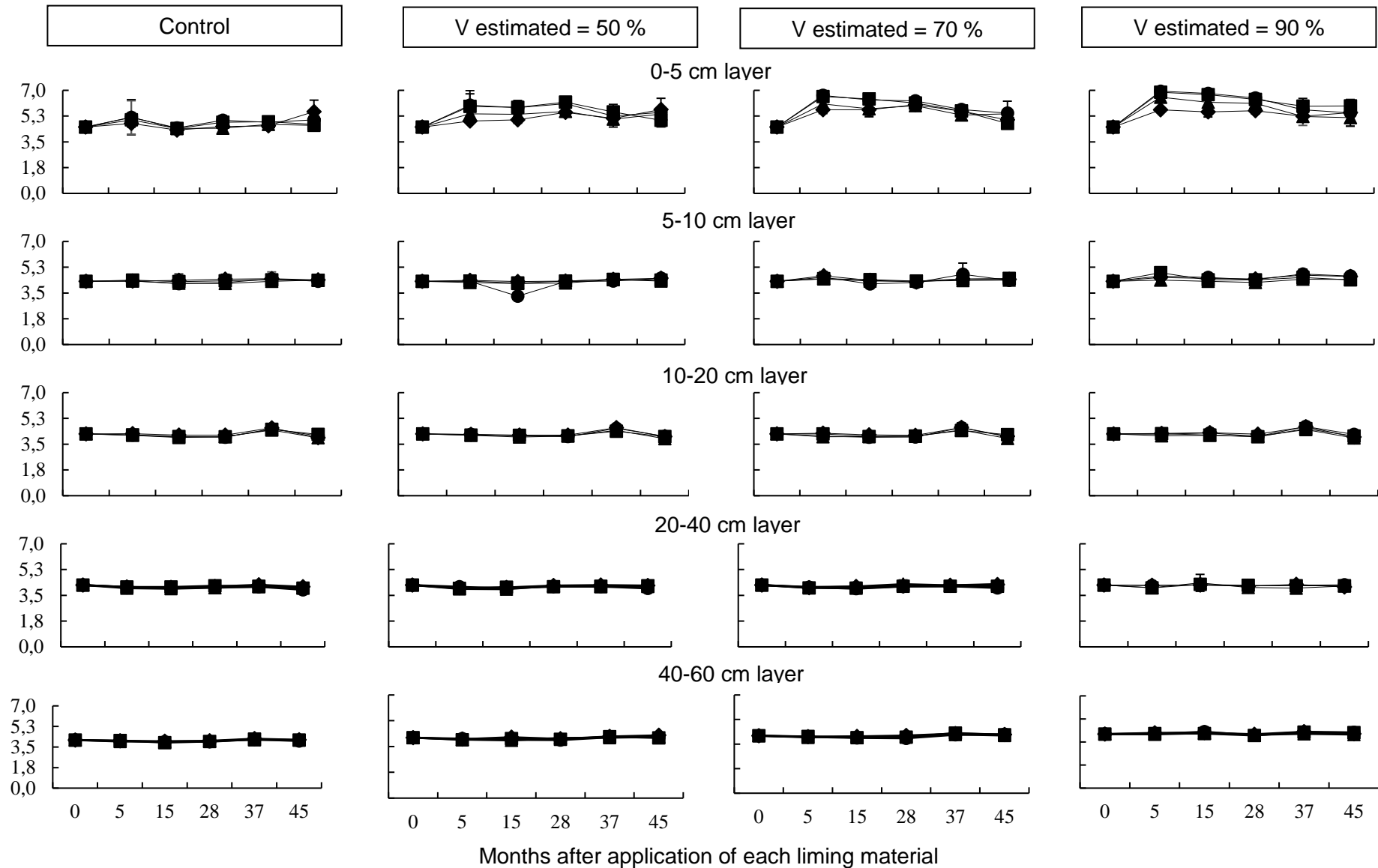


Figure 2. pH values (in CaCl_2 0.01 mol L^{-1}) of a Typic Distrudept ($n = 16 \pm$ standard deviation), after 0, 5, 15, 28, 37 and 45 months after the surface application of liming materials in the doses aiming the increase of the soil base saturation (V estimated) to 50, 70 and 90% besides control treatment, in each soil layer. (◆) Dolomitic limestone. (■) Granulated micronized calcite. (▲) Granulated micronized dolomite. (●) Carbonated suspension.

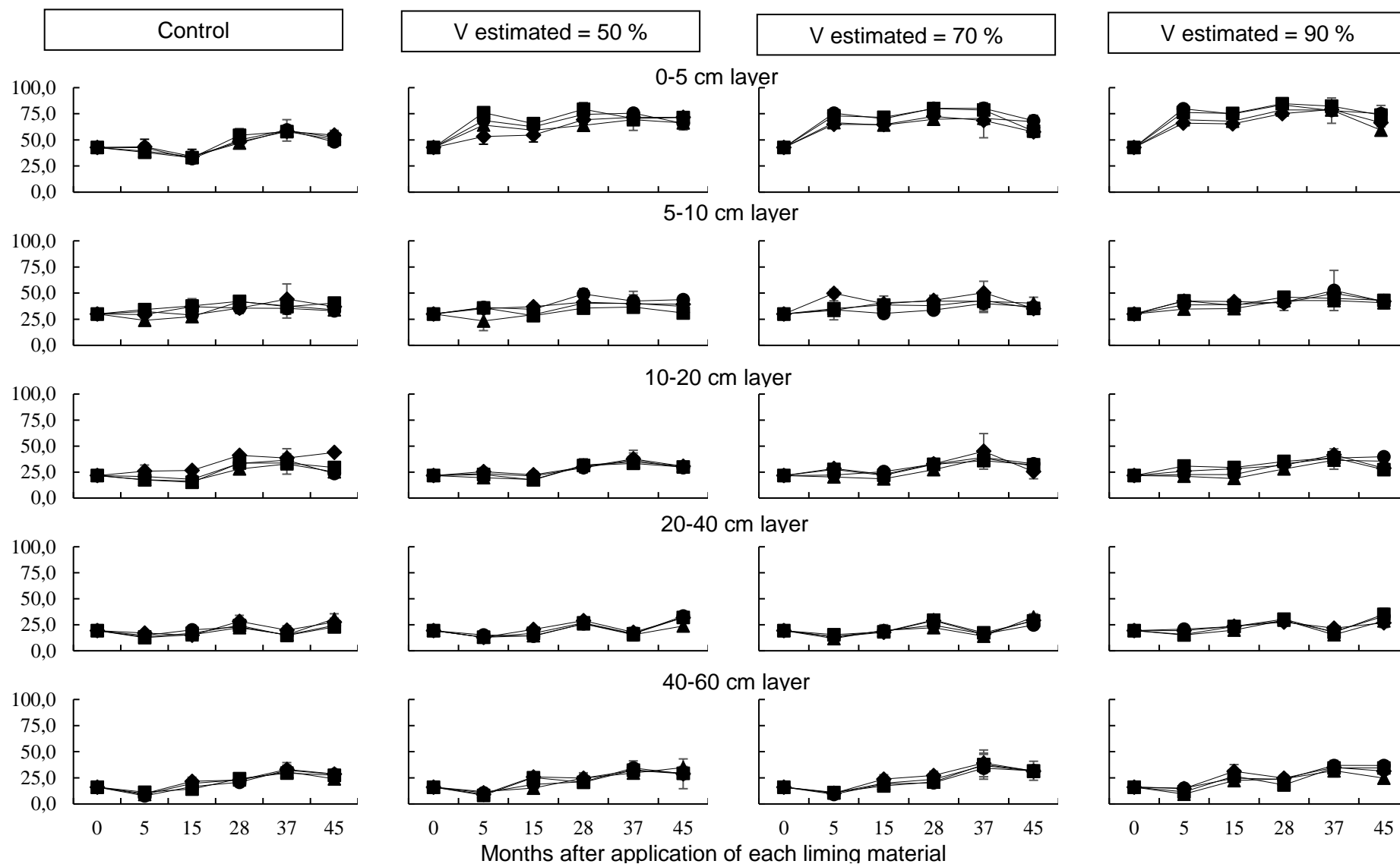


Figure 3. Soil base saturation (V), % ($n = 16 \pm$ standard deviation) of a Typic Distrudept, after 0, 5, 15, 28, 37 and 45 months after the surface application of liming materials in the doses aiming the increase of the soil base saturation (V estimated) to 50, 70 and 90% besides control treatment, in each soil layer. (◆) Dolomitic limestone. (■) Granulated micronized calcite. (▲) Granulated micronized dolomite. (●) Carbonated suspension.

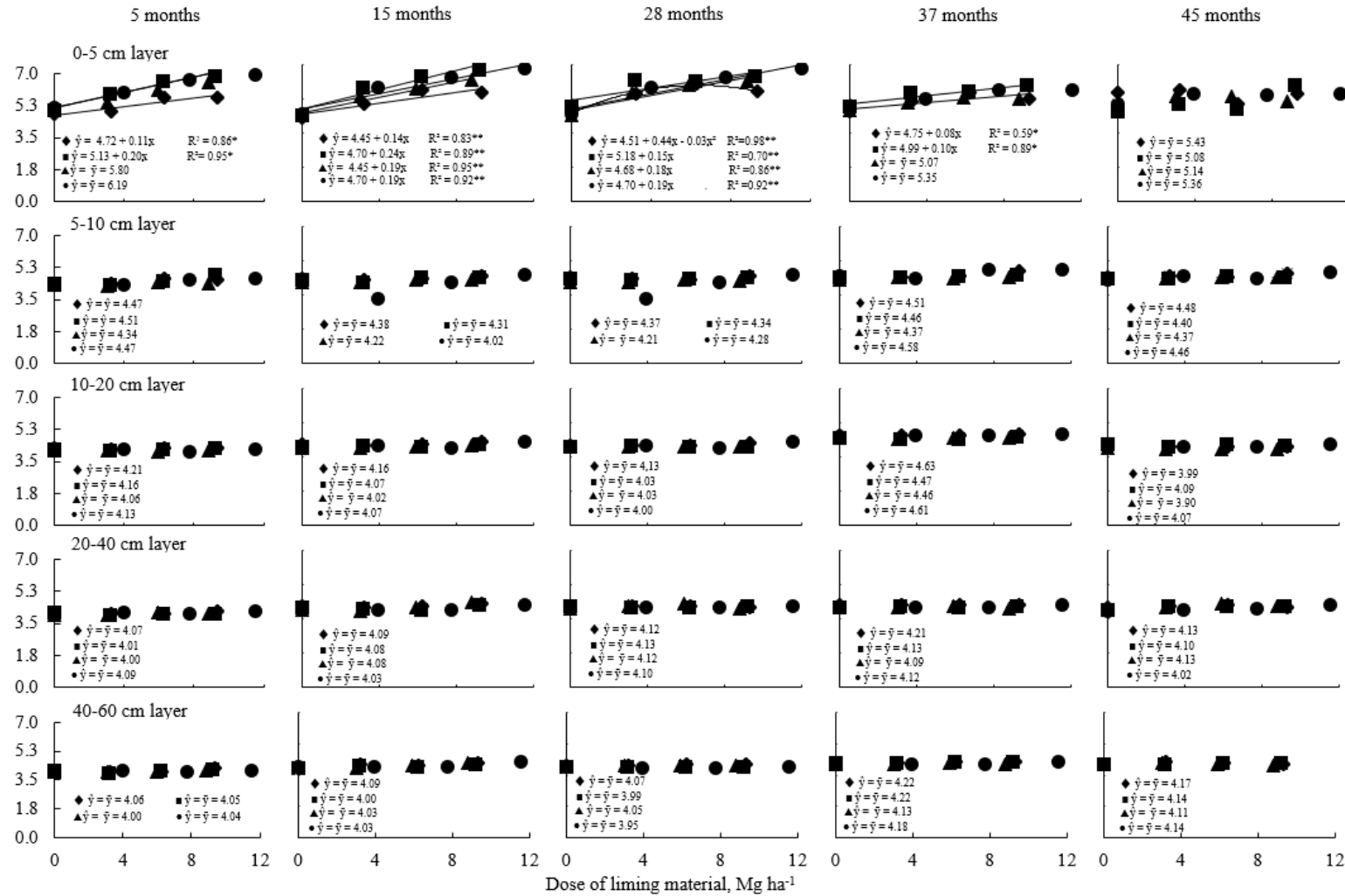


Figure 4. pH values (n = 4) of a Typic Distrudept, after 5, 15, 28, 37 and 45 months after the surface application of liming materials in the doses aiming the increase of the soil base saturation (V estimated) to 50, 70 and 90% besides control treatment, in deep layer. (♦) Dolomitic limestone. (■) Granulated micronized calcite. (▲) Granulated micronized dolomite. (●) Carbonated suspension. Vertical bars indicate the least significant difference (LSD). *: P < 0.05. **: P < 0.01.

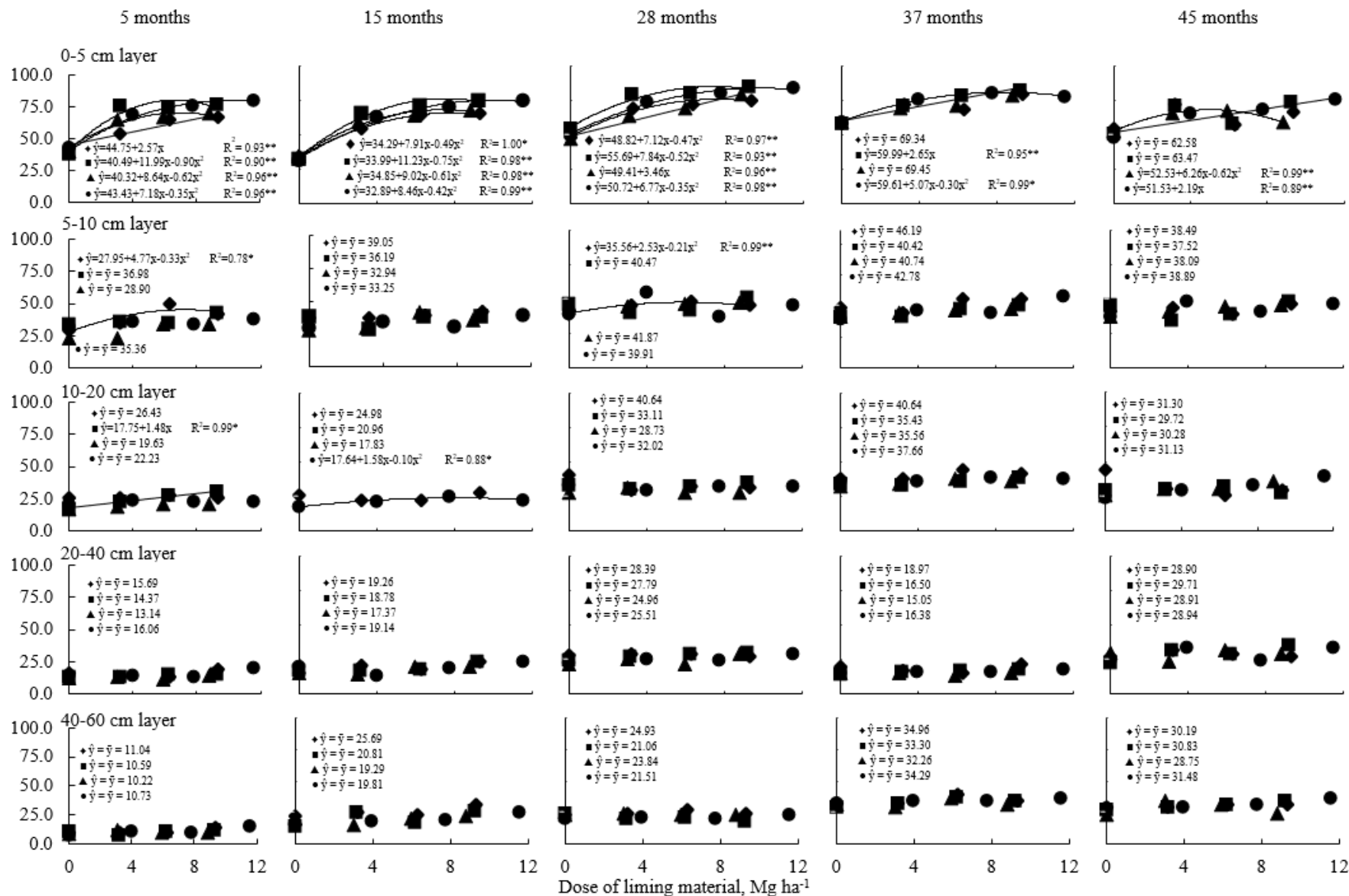


Figure 5. Soil base saturation (V) values (n = 4), %, of a Typic Distrudept, after 5, 15, 28, 37 and 45 months after the surface application of liming materials in the doses aiming the increase of the soil base saturation (V estimated) to 50, 70 and 90% besides control treatment, in deep layer. (♦) Dolomitic limestone. (■) Granulated micronized calcite. (▲) Granulated micronized dolomite. (●) Carbonated suspension. Vertical bars indicate the least significant difference (LSD). *: P < 0.05. **: P < 0.01.

Table 1. ANOVA significance for soil pH and base saturation (V).

Layer (cm)	Liming materials (LM)		Doses (D)		Months after application (M)		LM x D		LM x M		M x D		LM x D x M	
	F	Pr > F	F	Pr > F	F	Pr > F	F	Pr > F	F	Pr > F	F	Pr > F	F	Pr > F
pH														
0-5	9.97	0.0032	129.70	<0.0001	95.65	<0.0001	2.61	0.0065	4.71	<0.0001	12.82	<0.0001	0.93	0.6005
5-10	0.59	0.6354	9.23	<0.0001	7.87	<0.0001	0.99	0.4493	1.17	0.2935	1.34	0.1753	0.66	0.9545
10-20	1.58	0.2619	3.47	0.0168	125.14	<0.0001	0.57	0.8236	2.40	0.0028	0.83	0.6453	0.31	1.0000
20-40	0.52	0.6768	7.03	0.0001	10.23	<0.0001	1.70	0.0884	1.04	0.4132	2.53	0.0015	0.56	0.9890
40-60	1.48	0.2841	9.45	<0.0001	16.80	<0.0001	0.56	0.8265	0.84	0.6346	1.98	0.167	0.45	0.9990
V														
0-5	24.86	0.0001	304.47	<0.0001	523.88	<0.0001	10.25	<0.0001	9.44	<0.0001	38.27	<0.0001	7.69	<0.0001
5-10	3.09	0.0826	23.18	<0.0001	60.57	<0.0001	7.41	<0.0001	4.57	<0.0001	3.91	<0.0001	1.96	0.0006
10-20	3.77	0.0528	8.99	<0.0001	194.49	<0.0001	5.62	<0.0001	2.48	0.0020	2.60	0.0011	2.56	<0.0001
20-40	1.78	0.2207	21.70	<0.0001	216.79	<0.0001	2.07	0.0320	1.34	0.1772	2.65	0.0009	2.24	<0.0001
40-60	2.35	0.1406	11.22	<0.0001	303.02	<0.0001	1.68	0.0949	2.13	0.0090	3.01	0.0002	1.35	0.0806

DISCUSSION

The MLM (GMC, GMD and CS) increased the pH and V as from 5 months of your application while the DL increased as from 28 months of your application, in all doses applied (Figure 2 to 5). This fact shows that, the MLM presented faster reaction and higher responsiveness than DL, in soil with high buffering power and variable charge under NT, under field conditions. Similar results also were observed in soils under controlled conditions, where the MLM are able to increase the pH and the V in the first month of application [10,11]. Therefore, in short-term, the MLM can be strategic more efficient to soil acidity control and then, reduce loss of crops yield. These results, also point to differences of Typic Distrudept with others soils, as the Oxisol under NT, whom the DL (with 840 g kg⁻¹ of ECC) reacted after 48 months of application [15]. And also, as the Typic Hapludox under NT, whom the DL (with 710 g kg⁻¹ of ECC) reacted after 12 months of application [9]. However, the highest pH and V observed along the time, was only 28 months of MLM application and 45 months of DL application (Figure 2 to 5). Begging that, after 28 months of MLM application there was slight decrease in the pH and V, until 45 months (Figure 2 to 5). Hence, we concluded that, the MLM presented lower residual effect than DL.

All the major increased in the pH and V occurred more in the 0-5 cm layer than 5-60 cm layer, for all the liming materials and doses applied (Figure 2 to 5). This fact suggests that, the reaction of liming material applied in a Typic Distrudept (high buffering power and variable charge) under NT, occur only in the surface layer and not below the point of placement. Even though the MLM present fineness particles much lower than DL (MLM of 1.91 to 6.58 µm and DL of 269 µm) this fact not favored your reaction in deep layers (5-60 cm). In others soils, as the Haplic Umbisol, the reaction of DL (878 g kg⁻¹ of ECC) with fineness particle (< 0.25 µm) was much faster than with DL of coarsest particle (2-4 mm), during 36 months and 0-20 cm layer [1]. Already, the absence of liming material effect in 5-60 cm layer can be attributed the following factors that (i) the soil presented higher potential acidity [22], (ii) the dissolution/dissociation as far from acidity zone and reaction time [26]; (ii) subsoil pH is adequate [12], (iii) the neutralization of aluminum (Al³⁺) and of hydrogen (H⁺) on soil functional groups is limited [26], (iv) the soil buffering power is strongly by Al and iron (Fe) oxides [8], (v) lower water infiltration via macroporos [2] and (vi) lower adsorption/desorption of cations by organic anions soluble [17].

Also, in Typic Distrudept, can occur the reprecipitation of carbonate due to decrease of partial pressure of CO₂ (by microbial activity) and increase of solute concentration, limiting the acidity control only in 0-5 cm layer [3]. This layer may have occurred increase of microbial activity by liming material, favoring the organic matter mineralization and the decrease of the carbon stocks (less CO₂) [20].

The majority of Brazil, especially in the Paraná State, the liming requirement by V is calculated for 0-20 cm layer of soil in conventional tillage, but this also is used for NT [24]. However, in NT, with surface application and without incorporation of liming materials, the V estimated is not reached, across the 0-20 cm layer. But, only, in some part of 0-20 cm layers, as the 0-5 cm layer. All the major increased in the V occurred more in the 0-5 cm layer than 5-60 cm layer, for all the liming materials and doses applied (Figures 3 and 5). For the MLM in the dose of V to 50 %, the highest V observed along the time as much as the V after 45 months of application, it was of V obtained > V estimated, approximately 40 % greater. Already, in the dose of V to 70 %, the highest V observed, along the time, it was of V obtained > V estimated, approximately 10 % greater. Yet, in the dose of V to 70 %, the V after 45 months of application was of V obtained < V estimated, approximately 20 % smaller. For the MLM in the dose of V to 90 %, the highest V observed along the time as much as the V after 45 months of application, was of V obtained < V estimated, approximately 80 % smaller. This fact was stronger in MLM than DL. Begging that, among the MLM, the GMC was the only where V obtained equal the V estimated of 70 % (Figures 3 and 5). Therefore, the gap between the V estimated and measured is smaller in soil treatment with MLM than DL. This way, the MLM present greater assurance that what was applied really reacted. But, when the V obtained is higher than V estimated, can be occur a problem with the overliming in the pH in surface layer. This fact was common with surface application of CS in all the doses (Figures 3 and 5). The overliming in the pH may cause, in short-time, micronutrient unavailability [12]. Therefore, in short-term, the MLM can be strategic more efficient to increase and remain the V and then, reduce loss of crops yield.

As from results obtained, the doses of all liming materials more recommended is aiming V between 50 and 70 % for a Typic Distrudept under NT (Figure 2 to 5). Therefore, the dose aiming V over 70 % and below 50 % will not occur interesting results. In these doses and among the MLM, the GMC and CS were more efficient than others liming materials studied with regard to increase of pH and V. However, for Typic Distrudept the dose aiming V to 70 %, commonly used in Oxisol [6], may not be appropriate.

CONCLUSION

The micronized liming material increase and keeps pH and V values, only in the 0-5 cm layer, during 5 up to 45 months after surface application, without incorporation, in a Typic Distrudept under no-tillage. However, the fineness particles of micronized liming material do not favor the soil reaction in the 5-60 cm layer. The doses of all liming materials more recommended is aiming base saturation between 50 and 70 % for a Typic Distrudept. The gap between the soil base saturation estimated and obtained is smaller in soil treatment with micronized liming material than dolomitic lime, mainly in the 0-5 cm layer. Therefore, the liming materials, applied superficially and without incorporation, were not efficient to increase the pH and V values below the point of placement, in soils high buffering power and variable charge, as the Typic Distrudept.

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Conflicts of Interest: The authors declare no conflict of interest.

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