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Study on the efficacy of magnesium carbonate as ameliorant in lateritic soils of Kerala

Soniya VP and Bhindhu PS

Abstract

An incubation study was conducted by supplying three levels of magnesium carbonate with and without the addition of recommended dose of calcium carbonate (250 kg ha^{-1}) and organic manure (20 t ha^{-1}) to one kilogram of soil to study the effect of magnesium carbonate as ameliorant. Soil pH, EC and available Magnesium were determined at weekly intervals for four months. The fractions of magnesium in soil were determined before and after the experiment. Higher soil pH and available magnesium were recorded in treatment supplied with the highest dose of magnesium carbonate with the addition of organic manure and calcium carbonate throughout the incubation period. Maximum release of magnesium from magnesium carbonate was in the eighth (133.89 mg kg^{-1}) week and was on par with seventh (129.55 mg kg^{-1}) and ninth (129.97 mg kg^{-1}) after incubation and decreased thereafter. Fractions of magnesium in the initial soil and after incubation were in the order mineral Mg> exchangeable Mg> acid soluble Mg> organic complexed Mg> water soluble Mg. The variations in acid soluble and mineral fraction between treatments substantiates the presence of magnesium carbonate as a solid phase throughout the incubation period, which could be a potential slow-release magnesium fertilizer to plants.

Keywords: Lateritic soil, Soil pH, electrical conductivity, available magnesium, fractions of magnesium

Introduction

Magnesium is the eighth most abundant element in the earth's crust, comprising about two percent by weight and one of the dominant cations on the exchange complex of soil. About 90–98 percent of the soil Mg is incorporated in the crystal lattice structure of minerals, thus not directly available for plant uptake. Appreciable quantities of magnesium exist in soil minerals like olivine, amphibole, pyroxene, biotite, chlorite, serpentine, montmorillonite, vermiculite, brucite, schoenite, and epsom salt. Additionally, carbonates such as magnesite ($MgCO_3$) and dolomite ($MgCO_3$ + $CaCO_3$) also provide reasonable quantities of Mg ranging from 10 to 30 g kg^{-1} (Dechen *et al*., 2015) [5]. Bioavailable forms of Mg originate from weathering of magnesium-containing minerals. Owing to the variation of magnesium in the parent material and their degree of weathering, the total content of Mg in soil varies considerably between 0.05 and 0.5 percent (Grimme, 1991; Maguire and Cowan, 2002) [6, 11].

Different factors affect magnesium release from minerals and availability to plants. Soil pH has a direct effect on the availability of magnesium in soils. Mg availability in acidic soil is further reduced by competition from H, Al and Mn, whereas in alkaline soil, carbonate formation and excess concentrations of Na, K, and Ca reduce its availability (Wilkinson *et al*., 1990) [17]. Mengel and Kirkby (2001) [12] also reiterated that applying N, P, K fertilizers without a sufficient supply of magnesium accompanied by profound leaching in light-textured soil, makes magnesium deficiency a major concern in crop nutrition.

Lateritic soils occupy more than 50 percent of the total geographical area of Kerala (Krishnan *et al*. 1996) [10]. They have low pH, cation exchange capacity, effective cation exchange capacity and base saturation, with dominant presence of 1:1 clays and gibbsite along with hydroxy-interlayered vermiculites (HIV), Mica-HIV, and mica in the silt and clay fractions indicating the presence of significant amounts (>10%) of weatherable minerals (Chandran *et al*., 2005) [4]. Nair *et al*. (2013) [14] reported magnesium deficiency to the tune of 74 percent in the soils of Kerala, with only exemption in the soils of Central and Eastern Palakkad and Attapady hills. According to Bhindhu and Sureshkumar (2016) [2], available magnesium status in representative soil samples collected from different agro-ecological units of lateritic origin from Kerala varied from 22.25 to 96.20 mg kg^{-1}. The inability of lateritic soils to retain Mg on the exchange surface reveals the importance of managing magnesium nutrition in these soils.

Unlike other basic cations, magnesium is less strongly bound to soil charges and has high mobility in soils, thus prone to leaching losses. Application of soluble fertilizers like kieserite or magnesium sulphate poses problems related to leaching, especially when applied to sandy soils having high hydraulic conductivity and lateritic soils having low cation exchange capacity. There arises the importance of slow-release magnesium sources like dolomite, magnesite and calcined magnesite, which helps to mitigate the risk of leaching losses and deliver sufficient quantities as per requirement (Hardter *et al*. 2004) [8]. Applying magnesium carbonate can raise the soil pH apart from increasing the availability of magnesium in the soil, thereby improving cation retention under acidic conditions. The present study was undertaken in this background.

Materials and Methods

An incubation experiment was conducted with lateritic soil collected from Water Management Research Unit, Kerala Agricultural University, Vellanikkara ($13^0$32N and $76^0$26E), to study the effect of magnesium carbonate on soil properties. Three doses of magnesium as magnesium carbonate was added to 1 kg soil with and without recommended dose of calcium carbonate and organic manure and incubated for four months. The amount of magnesium carbonate to supply magnesium sufficient to theoretically raise the available magnesium status to 120 mg kg^{-1} (KAU, 2016) was taken as the optimum dose (100 percent) and one level above (150 percent) and one level below the optimum dose (50 percent) was added with and without the addition of recommended dose of calcium carbonate and organic manure (Table 1). The two levels of organic manure are 0 and 20 t ha^{-1} and that of calcium carbonate are 0 and 250 kg ha^{-1}, as per the package of practice recommendations of Kerala Agricultural University. The available magnesium content in the soil was 64 mg kg^{-1}. The amount of magnesium carbonate (AR grade; 28.82% Mg) required to raise the available magnesium status to 120 mg kg^{-1} of soil was taken as 0.1943g. The quantity of organic manure (vermicompost-ground and sieved through 0.5 mm sieve), calcium carbonate (AR grade) and magnesium carbonate supplied to 1kg soil as per the treatment are presented in table 1. Soil was maintained at field capacity and soil pH, EC and available magnesium were determined in the samples drawn at weekly intervals for four months. The fractions of magnesium were determined in soil before and after the experiment as per the procedure given by Mokwunye and Melsted, (1972) [13]. The data generated were analyzed for variance as factorial CRD with the treatments imposed (T) and the time interval (W) as main factors.

Table 1: Treatment combinations of incubation experiment

Treatments	Treatment combination	Organic manure (O) (g kg^{-1})	Calcium carbonate (L) (g kg^{-1})	Magnesium carbonate (M) (g kg^{-1})
T_1	$O_0L_0M_1$	0	0	0.0972
T_2	$O_0L_0M_2$	0	0	0.1943
T_3	$O_0L_0M_3$	0	0	0.2915
T_4	$O_0L_1M_1$	0	0.1116	0.0972
T_5	$O_0L_1M_2$	0	0.1116	0.1943
T_6	$O_0L_1M_3$	0	0.1116	0.2915
T_7	$O_1L_0M_1$	8.93	0	0.0972
T_8	$O_1L_0M_2$	8.93	0	0.1943
T_9	$O_1L_0M_3$	8.93	0	0.2915
T_{10}	$O_1L_1M_1$	8.93	0.1116	0.0972
T_{11}	$O_1L_1M_2$	8.93	0.1116	0.1943
T_{12}	$O_1L_1M_3$	8.93	0.1116	0.2915

Results and Discussion

Effect of magnesium treatments on soil pH

Effect of different levels of magnesium carbonate with or without calcium carbonate and organic matter on soil pH at weekly intervals of incubation for sixteen weeks showed significantly higher soil pH in treatment T_{12} ($O_1L_1M_3$) with the addition of calcium carbonate (250 kg ha^{-1}), organic manure (20 t ha^{-1}) and higher dose of magnesium carbonate (Table 2). The significant rise in soil pH is due to the addition of both calcium carbonate with a neutralizing value of 100% and magnesium carbonate with 118.61%. A significant difference in soil pH between T_6 ($O_0L_1M_3$) (5.12) and T_{12} ($O_1L_1M_3$) (5.32) indicates the release of basic cations from vermicompost. The rise in pH due to application of vermicompost was attributed by Bekele *et al.* (2018) [1] to its high content of basic cations and slightly alkaline pH, which could reduce soil acidity by replacing the acidic Cations from the exchange sites.

Over the period of incubation, significantly higher soil pH compared to initial pH (4.7) observed one week after incubation indicating the efficacy of the liming materials added. The calcium and magnesium released from $CaCO_3$ and $MgCO_3$ replace H^+ ions on the exchange sites, which are neutralized by the anion CO_3^{2-}. Watling *et al.* (2010) [15] showed that liming materials of size less than 0.5mm can raise soil pH within one week of application. It was observed that soil pH at the end of the experiment was higher than the initial soil pH in all the treatments indicating the persistence of magnesium carbonate throughout the incubation period. The interaction effect of treatments and period of incubation showed that significantly higher soil pH in treatment T_{12} one week after incubation (5.32).

Table 2: Effect of magnesium treatments on soil pH

		Weeks after incubation (W)																
Treatments (T)		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Mean**
T_1	$O_0L_0M_1$	4.82	4.81	4.81	4.75	4.71	4.73	4.80	4.78	4.82	4.65	4.79	4.81	4.72	4.72	4.74	4.73	4.76
T_2	$O_0L_0M_2$	4.94	4.85	4.86	4.83	4.75	4.82	4.88	4.86	4.84	4.79	4.81	4.84	4.77	4.74	4.79	4.77	4.82
T_3	$O_0L_0M_3$	5.02	4.87	4.95	4.82	4.82	4.96	4.91	4.92	4.88	4.89	4.92	4.87	4.87	4.85	4.82	4.87	4.89
T_4	$O_0L_1M_1$	4.83	4.77	4.86	4.81	4.77	4.96	4.82	4.81	4.85	4.75	4.81	4.82	4.77	4.73	4.84	4.75	4.81
T_5	$O_0L_1M_2$	5.04	4.81	4.93	4.87	4.86	4.83	4.88	5.02	4.93	4.76	4.84	4.90	4.84	4.82	4.86	4.77	4.87
T_6	$O_0L_1M_3$	5.12	4.95	5.06	4.90	5.04	4.95	4.90	5.01	4.97	4.93	4.94	5.01	4.94	4.91	4.93	4.86	4.96
T_7	$O_1L_0M_1$	4.88	4.85	4.93	4.94	4.85	4.85	4.82	4.93	4.93	4.83	4.85	4.88	4.82	4.84	4.74	4.83	4.86
T_8	$O_1L_0M_2$	5.11	4.92	5.01	4.94	5.01	4.94	4.92	5.02	5.06	4.80	4.96	4.94	4.88	4.90	4.91	4.93	4.95
T_9	$O_1L_0M_3$	5.16	5.07	5.09	4.98	5.06	4.98	5.02	5.06	5.07	5.03	5.02	5.03	5.05	5.03	4.96	5.08	5.04
T_{10}	$O_1L_1M_1$	5.24	4.95	5.09	4.95	5.00	5.02	5.00	5.04	5.08	4.99	4.96	5.04	4.95	4.91	4.86	4.94	5.00
T_{11}	$O_1L_1M_2$	5.24	5.04	5.13	5.01	5.13	5.09	5.05	5.09	5.11	5.03	5.05	5.06	4.97	5.01	4.96	5.03	5.06
T_{12}	$O_1L_1M_3$	5.32	5.12	5.24	5.15	5.14	5.13	5.10	5.14	5.15	5.11	5.12	5.09	5.12	5.08	5.16	5.10	5.14
	Mean	5.06	4.91	4.99	4.91	4.93	4.94	4.92	4.97	4.97	4.88	4.92	4.94	4.89	4.88	4.88	4.89	
CD-T (0.05) -0.01			CD-W(0.05) -0.011				CD – T x W (0.05) -0.039											

Effect of magnesium treatments on electrical conductivity of soil: The initial status of soil EC was 0.07 dS m^{-1}. The treatments imposed produced significant changes in soil EC over the period of time (Figure 1). The treatment T_{12} with the addition of calcium carbonate (250 kg ha^{-1}), organic manure (20 t ha^{-1}) and magnesium carbonate at 150% of the optimum dose recorded significantly higher soil EC (0.18 dS m^{-1}), which can be attributed to the addition of higher quantity of bases to the soil. The effect of incubation period on soil EC revealed significantly higher EC (0.20 dS m^{-1}) at the end of the incubation period. This substantiates the release of basic cations persisted throughout the incubation period. The interaction effect of treatments and period of incubation showed significantly higher EC to be recorded in T_9 (0.25 dS m^{-1}) at sixteen weeks after incubation which was on par with EC recorded at thirteen weeks after incubation in treatment T_{12} (0.23 dS m^{-1}).

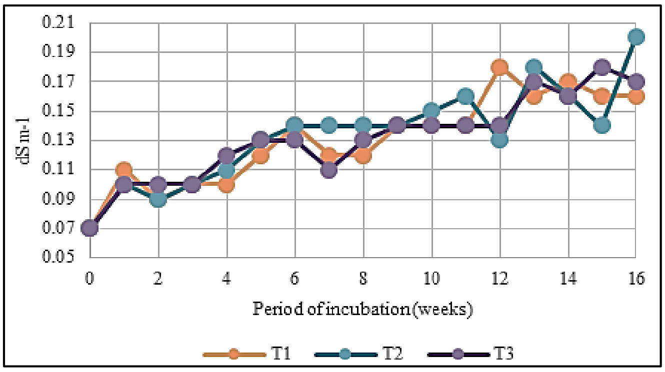

Fig 1a: Effect of different levels of MgCO3 on soil EC at 0kg ha-1 CaCO3 and 0t ha-1 organic manure

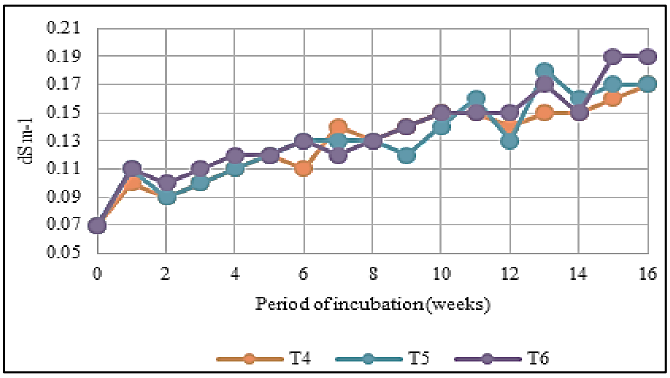

Fig 1b: Effect of different levels of MgCO3 on soil EC at 250kg ha-1 CaCO3 and 0t ha-1 organic manure

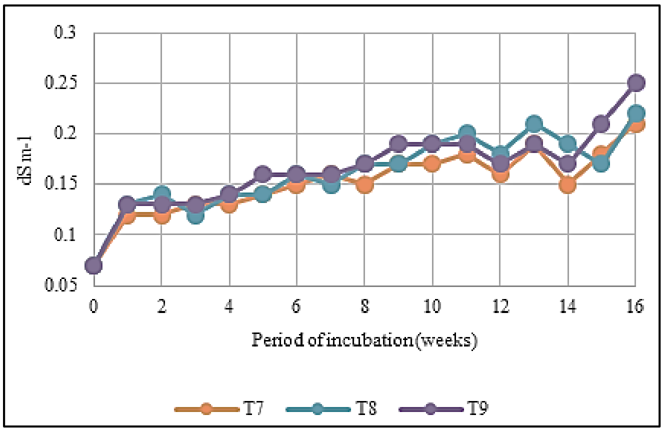

Fig 1c: Effect of different levels of MgCO3 on soil EC at 0kg ha-1 CaCO3 and 20t ha-1 organic manure

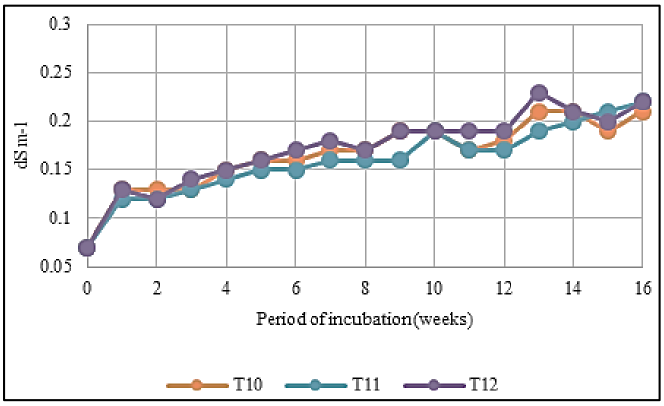

Fig 1d: Effect of different levels of MgCO3 on soil EC at 250kg ha-1 CaCO3 and 20t ha-1 organic manure

Fig 1: Effect of treatments on soil EC over the period of incubation

Effect of magnesium treatments on available Mg

Available magnesium showed significant differences among treatments (Table 3). A significantly higher status of available magnesium was recorded in treatment T_{12} ($O_1L_1M_3$) (142.07 mg kg^{-1}), which was on par with T_9 ($O_1L_0M_3$) (141.64 mg kg^{-1}) which is obviously due to the addition of higher level of magnesium carbonate in these treatments. The lowest value of available Mg was recorded by T_1 with a mean of 88.95 mg kg^{-1}.

Over the period of incubation, significantly higher content of available magnesium was recorded in the eighth week after incubation (133.89 mg kg^{-1}). It was on par with the nutrient status seven (129.55 mg kg^{-1}) and nine weeks (129.97 mg kg^{-1}) after incubation. This indicates the period of maximum release from magnesium carbonate added. A further reduction noted might be due to the release of other cations from the exchange sites to maintain the equilibrium between the soil solid phase and solution phase. The interaction effect of treatments and period of incubation showed significantly higher available magnesium content in treatment T_{12} (170.26 mg kg^{-1}) at nine weeks after incubation.

Table 3: Effect of treatments on available magnesium (mg kg^{-1}) in soil during incubation

Treatments(T)	**Weeks after incubation (W)**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**Mean**
T_1	81.90	96.68	81.05	83.56	81.61	81.35	107.60	112.26	96.36	78.86	82.6	82.25	99.66	90.15	83.01	88.95
T_2	97.01	116.15	113.75	100.00	102.35	103.9	126.10	136.80	121.86	99.31	108.51	94.95	120.05	116.41	108.46	110.58
T_3	114.80	135.96	151.41	145.56	142.01	113.81	133.20	150.80	136.71	109.21	116.05	114.45	129.12	131.31	137.98	130.21
T_4	76.11	103.25	88.86	85.71	87.00	82.46	105.15	111.16	102.30	83.71	89.10	88.10	101.75	88.31	95.21	92.22
T_5	92.55	113.40	98.96	97.56	97.20	112.75	125.35	127.66	126.16	98.06	106.06	103.90	121.55	110.91	108.30	108.90
T_6	111.48	142.61	133.65	125.9	116.16	121.51	144.05	147.85	152.51	114.91	128.15	120.88	144.38	131.05	141.80	131.57
T_7	91.61	112.25	102.15	94.00	86.51	97.20	115.00	104.95	105.60	89.16	100.70	92.81	104.75	94.40	82.85	98.27
T_8	111.63	141.55	124.35	113.85	110.35	109.91	131.11	138.40	135.56	112.71	129.30	121.50	128.88	127.60	117.40	123.30
T_9	130.75	158.13	148.10	132.51	140.26	135.01	148.96	158.88	166.91	123.16	132.15	133.20	143.11	141.05	136.70	141.64
T_{10}	95.90	108.76	104.11	92.80	94.05	97.11	117.71	116.90	107.55	97.56	93.40	94.61	107.88	106.45	101.40	102.11
T_{11}	111.01	137.76	136.76	110.45	104.65	118.40	143.06	138.10	137.85	103.43	116.76	115.46	129.61	124.86	124.66	123.13
T_{12}	117.41	155.26	153.80	138.11	132.60	131.51	157.31	163.00	170.26	123.26	138.10	136.6	140.63	132.26	142.95	142.07
Mean	102.68	126.81	119.74	110.00	107.89	108.74	129.55	133.89	129.97	102.78	111.74	108.22	122.61	116.23	115.06	88.95
CD(0.05)- T- 1.075				CD(0.05)- W- 1.241			CD(0.05)- TxW- 4.299									

Effect of magnesium treatments on fractions of Mg

The total magnesium in soil was partitioned into water soluble, exchangeable, organic-complexed, acid soluble and mineral fractions as per the procedure outlined by Mokwunye and Melsted, (1972) [13]. Water soluble fraction was smallest of all the fractions of magnesium. The initial content of water soluble magnesium was 3.52 mg kg^{-1}. After the incubation experiment, the water soluble fraction in soil ranged from 9.19 to 18.82 mg kg^{-1} (Table 4). Significantly higher content of this fraction was recorded in treatment T_{12} with the treatment combination of $O_1L_1M_3$ (18.82 mg kg^{-1}) and was on par with T_8 ($O_1L_0M_2$) (17.58 mg kg^{-1}). The exchangeable fraction of Mg (Ex-Mg) in soil increased from the initial value of 77.30 mg kg^{-1} and ranged from 94.00 mg kg^{-1} (T_1) to 143.53 mg kg^{-1} (T_{12}). The highest content of exchangeable magnesium was observed in T_{12} ($O_1L_1M_3$) (143.53 mg kg^{-1}) and was on par with T_9 ($O_1L_0M_3$) (138.73 mg kg^{-1}). This might be because of higher release of magnesium from treatments with a higher level of added magnesium carbonate. The organic-complexed (Or-c-Mg) fraction varied from 9.46 to 12.53 mg kg^{-1} compared to the initial status of 9.00 mg kg^{-1}. The organic-complexed fraction was significantly higher in T_{12} (12.53 mg kg^{-1}) and T_{11} (12.30 mg kg^{-1}), which might have been contributed through higher microbial biomass in these treatments due to a significant increase in soil pH. Significantly higher content of acid soluble (Ac-s-Mg) fraction was recorded in T_{11} ($O_1L_1M_2$) (53.93 mg kg^{-1}) and mineral fraction in T_9 ($O_1L_0M_3$) (1022.23 mg kg^{-1}). The higher content of acid soluble and mineral fraction in the treatments in comparison to the initial status (38.33 mg kg^{-1}) substantiates the presence of magnesium carbonate as a solid phase throughout the incubation period. White and Munro (1981) reported a release of 43% of added magnesium from dolomite after 200 days in a pot culture experiment with the soil of pH 5.5.

Table 4: Effect of treatments on fractions of magnesium

	Treatment combinations			**WS Mg**	**Ex Mg**	**Or-c Mg**	**Ac-s Mg**	**Min Mg**	**Tot Mg**
Treatments	**Organic manure**	**Calcium carbonate**	**Magnesium Carbonate**						
	(g kg^{-1})			**(mg kg^{-1})**					
T_1	0	0	0.0972	9.19^{g}	94.00^{f}	9.46^{e}	47.53^{cd}	986.77^{d}	1154.36^{f}
T_2	0	0	0.1943	14.43^{ef}	111.23^{d}	9.63^{e}	47.50^{d}	984.81^{d}	1175.01^{de}
T_3	0	0	0.2915	17.44^{bc}	124.03^{c}	10.03^{e}	47.33^{de}	992.87^{cd}	1186.68^{d}
T_4	0	0.1116	0.0972	13.88^{f}	102.83^{e}	10.10^{de}	47.63^{cd}	1001.03^{bc}	1182.87^{de}
T_5	0	0.1116	0.1943	14.02^{ef}	111.03^{d}	10.53^{cde}	44.30^{fg}	984.60^{d}	1171.88^{e}
T_6	0	0.1116	0.2915	14.14^{ef}	136.53^{b}	11.26^{bc}	45.50^{ef}	985.25^{d}	1186.68^{d}
T_7	8.93	0	0.0972	15.21^{de}	109.93^{d}	11.23^{bcd}	43.50^{g}	999.40^{bc}	1199.10^{c}
T_8	8.93	0	0.1943	17.58^{ab}	124.40^{c}	10.30^{cde}	44.93^{fg}	1009.27^{b}	1213.88^{b}
T_9	8.93	0	0.2915	16.50^{bc}	138.73^{ab}	11.30^{bc}	44.93^{fg}	1022.23^{a}	1241.03^{a}
T_{10}	8.93	0.1116	0.0972	17.37^{bc}	109.90^{d}	9.73^{e}	50.40^{b}	991.87^{cd}	1200.09^{c}
T_{11}	8.93	0.1116	0.1943	16.28^{cd}	118.06^{c}	12.30^{ab}	53.93^{a}	1005.91^{b}	1213.88^{b}
T_{12}	8.93	0.1116	0.2915	18.82^{a}	143.53^{a}	12.53^{a}	49.40^{bc}	1009.42^{b}	1241.10^{a}
Treatment means with common superscript do not differ significantly									
Initial soil fractions				3.52	77.30	9.00	38.33	981.930	1142.26

Conclusion

The higher pH, EC and available magnesium was recorded in treatment supplied with higher dose of magnesium carbonate with the addition of organic manure and calcium carbonate. The fractions of magnesium in all treatments were in the order mineral Mg> exchangeable Mg> acid soluble Mg> organic complexed Mg> water soluble Mg. treatments were in the order mineral Mg> exchangeable Mg> acid soluble Mg> organic complexed Mg> water soluble Mg. The variations in acid soluble and mineral fraction between treatments substantiates the presence of magnesium carbonate as a solid phase in soil. The result suggests that magnesium carbonate could be an efficient magnesium fertilizer compared to other soluble sources under prevailing rainfall conditions of Kerala.

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