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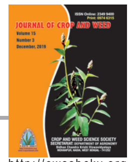

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Optimization of magnesium and boron dosage in cardamom grown in Idukki district of Kerala

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ABSTRACT

Experiments were laid out in cardamom plantations of Idukki district to optimize the dosage of magnesium and boron. The trials for the optimization of Mg and B dosage were conducted separately. For Mg, treatments imposed include soil application of five doses of $MgSO_4$ @ 20, 40, 60, 80, 120 kg ha^{-1} and a control (without Mg source). In the case of B, treatments imposed include soil application of B @ 0.5, 1, 1.5, 2.0 kg ha^{-1}, and foliar application of borax @ 0.2 % and control treatment without the application of B source. Magnesium and boron treatments were imposed separately on cardamom plants which showed the deficiency symptoms of corresponding nutrient. In Mg trial, the highest cardamom yield, highest nutrient content in index leaf and highest availability of secondary and micronutrient in the soil were obtained from the treatment which received $MgSO_4$ @ 120 kg ha^{-1}. Similarly for B trial, highest cardamom yield, highest nutrient content in index leaf and highest availability of secondary and micronutrient in the soil were obtained from treatment which received foliar application of borax @ 0.2 %. Critical level of Mg and B in the index leaf of cardamom was found to be 0.31 % and 16 mg kg^{-1}, respectively. The critical limit of available Mg and B content in soil was delineated as 160 and 4 mg kg^{-1}, respectively.

Keywords: *Borax, Boron, Index leaf, Cardamom, Magnesium, Magnesium sulphate, Nutrient availability, Yield*

Small cardamom (*Elettaria cardamomum*) is one of the oldest known spices and is called as queen of spices. Cardamom is considered as the third most expensive spice in the world after saffron and vanilla. Evergreen forest of Western Ghats of South India is the centre of origin and natural habitat of this crop. The climatic condition prevailing in Western Ghats belt of Kerala is ideal for its cultivation and is widely cultivated in Kumily, Annavilasam, Vandanmedu, Nedumkandam, Udumbanchola, Shanthampara and Poopara regions of Idukki district of Kerala. Cardamom is often referred as queen of spices owing to its pleasant aroma and taste is considered to be of the commodity which fetches premium price in the global market.

Kerala, the land of spices secured a fairly good position in global spice market with its quality. Extreme care needs to be taken for production of good quality cardamom by providing proper nutrient conditions in the soil after overcoming exiting nutrient deficiencies. Due to high annual rainfall, Kerala soils are acidic in nature and deficient in base forming nutrients like calcium (Ca), magnesium (Mg) etc. In the soil survey conducted, it was found that some areas under cardamom plantations of Idukki district were deficient in magnesium (Mg) and some other areas in boron (B). Both these nutrients are essential for crop production.

Mg has a key role in growth cycle of any crop as it is essential for chlorophyll synthesis and enzyme transfer mechanism. Magnesium deficiency is very common in acidic soil of Kerala, consequent to its high mobility resulting in leaching loss under very high annual rainfall conditions. Also intensive cropping with less addition of organic manures accelerated the condition. Deficiency of Mg results in interveinal chlorosis on older leaves and reduced crop growth.

Micronutrient B is very essential for reproduction, pollen fertility and cell wall stability (Chormova *et al.*, 2014). It also plays an important role in photosynthesis and carbon metabolism in plants (Wang *et al.,* 2015; Mishra and Heckathorn, 2016). Deficiency of B retards plant growth and leaf area expansion. It also causes dieback of shoot, leaf necrosis and decreased crop yield and quality (Wang *et al*., 2015). So, an attempt was made to optimize the dosage of Mg and B in cardamom plants grown in the nutrient deficient areas of Idukki district.

MATERIALS AND METHODS

Initial soil sampling

Twenty five geo-referenced soil samples each were collected from cardamom plantations of Senapathi and Rajakumari grama panchayat of Nedumkandam block (AEU 16) of Idukki district and the samples were analysed to delineate areas deficient in Mg and B. Based on the analytical data, convenient plots were chosen from the standing crop of cardamom where Mg and B found deficient and were analysed for initial physico-chemical properties (Table 1).

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Field lay out

The field experiment was laid out in the Mg and B deficient areas in 2017-18 and 2018-19. The experiment was conducted on cardamom variety PV-1 (4 years old), planted at a spacing of 2 x 2 m. In order to optimize the dosage of magnesium and boron in cardamom grown in Mg and B deficient areas, treatments were imposed separately on cardamom plants after optimizing all other nutrients except for the nutrient that given as treatment. Before imposing the treatments, the experimental site was limed to neutralize acidic soil reaction and all other nutrients were optimized based on the soil test data through the external application of fertilizers. In the Mg optimization experiment, treatments imposed were soil application of five doses of $MgSO_4$ @ 20, 40, 60, 80, 120 kg ha^{-1} and a control without the application of Mg source. Similarly in B experiment, treatments imposed were soil application of B @ 0.5, 1, 1.5, 2.0 kg ha^{-1}, and foliar application of borax @ 0.2 % and control treatment without the application of B source. The treatments were imposed in April-May and September-October as two split doses.

Soil sampling

After the seasonal harvest of cardamom at August 2018 and 2019, soil samples from each treatment Mg and B experiment were collected at 0- 15 cm depth and were processed for chemical analysis. pH was determined by potentiometry and EC by conductivity, Available Ca and Mg was extracted with neutral normal ammonium acetate and determined in ICP-OES. Available S was determined by 0.15% $CaCl_2$ extraction and turbidimetry. Available Fe, Mn, Zn and Cu was extracted with 0.1 M HCl and available B was extracted with hot water and these elements were quantified using ICP-OES (Jackson, 1973).

Plant sampling

After the seasonal harvest of August 2018 and 2019, index leaf (2nd and 3rd leaf from apex) of cardamom plant was collected from each treatment for plant analysis. Collected plant samples were washed and then air dried followed by oven drying at 60 ± 5Ú C. The oven dried plant samples were ground in to fine powder before analysis.

N content in the index leaf was determined by Micro kjeldahl digestion in H_2SO_4 followed by distillation. For the analysis of other nutrients in index leaf, samples were digested with nitric-perchloric acid mixture in the ratio 9:4 and P was determined by vanado-molybdo yellow colour method and K by flame photometry. S content in the digest was determined by turbidimetry and Fe, Cu, Zn, Mn and B using ICP-OES (Piper, 1942).

Data analysis

The data obtained were statistically analyzed to check whether there is significant difference among the treatments. The critical level of Mg and B in the soil and cardamom plants was determined using Cate and Nelson method (Cate and Nelson, 1971).

RESULTS AND DISCUSSION

The treatments imposed had significantly influenced the concentration of nutrients in the index leaf and yield of cardamom plants and has enhanced the availability of secondary and micronutrients in the soil.

Effect of treatments on nutrient concentration in index leaves

The nutrient content in the index leaves significantly varied among the treatments (Table 2 and 3). In Mg experiment, the highest nutrient content in the index leaves *viz.* N (2.88 %), P (0.20 %), K (1.82 %), Ca (0.90 %), Mg (0.47 %), S (0.42 %), Fe (173.82 mg kg^{-1}), Mn (51.20 mg kg^{-1}), Zn (14.87 mg kg^{-1}), Cu (7.11 mg kg^{-1}) and B (14.34 mg kg^{-1}) was recorded in the treatments that received $MgSO_4$ @ 120 kg ha^{-1}.

In B experiment, the highest nutrient content in the index leaves *viz.* N (2.38 %), P (0.19 %), K (1.80 %), Ca (0.82 %), Mg (0.29 %), S(0.16 %), Fe (133.82 mg kg^{-1}), Mn (57.00 mg kg^{-1}), Zn (13.87 mg kg^{-1}), Cu (4.32 mg kg^{-1}) and B (17.44 mg kg^{-1}) was obtained for the treatment that received foliar application of borax @ 0.2 %.

Table 1: Initial soil parameters of experimental area

Soil parameters	Values
pH	4.85
EC	0.23
Available N	322 kg ha^{-1}
Available P_2O_5	68 kg ha^{-1}
Available K	244 kg ha^{-1}
Available Ca	432 mg kg^{-1}
Available Mg	94.89 mg kg^{-1}
Available S	14.15 mg kg^{-1}
Available Fe	25.64 mg kg^{-1}
Available Zn	4.02 mg kg^{-1}
Available Mn	3.98 mg kg^{-1}
Available Cu	3.87 mg kg^{-1}
Available B	2.66 mg kg^{-1}

Nutrient content in the index leaf is a measure of nutrient availability from the soil and nutrient uptake by crop plant. When there is an optimum balance among the nutrients in the soil, the nutrient uptake by crop plants will be increased (Morgan and Connolly, 2013). As there is a severe deficiency of Mg in the soil, a higher dosage of Mg is required for ameliorating the deficiency and to

Table 2: Effect of different levels of Mg on concentration of nutrients in the index leaf and yield of cardamom (pooled mean of 2018 and 2019)

Treatments	Nutrient content in index leaf											Yield
	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B	(kg plant^{-1})
			%					mg kg^{-1}				
T_1- Soil application $MgSO_4$ @ 20 kg ha^{-1}	2.69	0.15	1.51	0.68	0.33	0.28	153.11	43.35	12.13	5.38	12.64	3.28
T_2- Soil application $MgSO_4$ @ 40 kg ha^{-1}	2.72	0.16	1.52	0.68	0.36	0.31	155.42	44.03	12.96	5.69	12.80	3.53
T_3- Soil application $MgSO_4$ @ 60 kg ha^{-1}	2.75	0.16	1.61	0.79	0.38	0.31	159.64	45.82	13.05	6.11	13.93	3.77
T_4- Soil application $MgSO_4$ @ 80 kg ha^{-1}	2.76	0.17	1.67	0.87	0.41	0.36	160.45	49.15	13.72	6.45	14.07	4.86
T_5- Soil application $MgSO_4$ @ 120 kg ha^{-1}	2.88	0.20	1.82	0.90	0.47	0.42	173.82	51.20	14.87	7.11	14.34	5.49
T_6- Control	2.13	0.13	1.26	0.73	0.16	0.25	35.19	38.63	10.25	4.69	11.98	2.99
LSD (0.05)	**0.78**	**0.04**	**0.36**	**0.39**	**0.07**	**0.09**	**12.15**	**3.98**	**2.31**	**0.89**	**0.76**	**0.87**

Table 3: Effect of different levels of B on concentration of nutrients in the index leaf and yield of cardamom (pooled mean of 2018 and 2019)

Treatments	Nutrient content in index leaf											Yield
	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B	(kg plant^{-1})
			%				mg kg^{-1}					
T_1- Soil application Borax @ 0.5 kg ha^{-1}	2.34	0.13	1.44	0.64	0.25	0.28	120.11	33.15	11.13	3.28	15.64	3.17
T_2- Soil application Borax @ 1.0 kg ha^{-1}	2.35	0.16	1.46	0.64	0.25	0.31	120.42	41.03	12.16	3.49	16.39	4.50
T_3- Soil application Borax @ 1.5 kg ha^{-1}	2.35	0.16	1.49	0.69	0.26	0.26	129.64	45.82	12.75	3.76	16.93	4.63
T_4- Soil application Borax @ 2.0 kg ha^{-1}	2.37	0.17	1.52	0.77	0.26	0.33	131.45	49.15	12.98	4.11	17.27	4.73
T_5- Foliar application Borax @ 0.2 %	2.38	0.19	1.80	0.82	0.29	0.16	133.82	57.00	13.87	4.32	17.44	5.24
T_6- Control	2.29	0.10	1.26	0.59	0.21	0.56	118.19	28.63	8.25	3.09	9.68	2.98
LSD (0.05)	**0.13**	**0.02**	**0.16**	**0.09**	**0.07**	**0.09**	**6.35**	**4.48**	**0.73**	**0.96**	**0.92**	**0.69**

Table 4 : Effect of different levels of Mg on soil chemical properties and availability of secondary and micronutrients in the cardamom plantation (pooled mean of 2018 and 2019)

Treatments	pH	ECdS m^{-1}	Available Ca	Available Mg	Available S	Available Fe	Available Mn	Available Zn	Available Cu	Available B
						mg kg^{-1}				
T_1- Soil application $MgSO_4$ @ 20 kg ha^{-1}	5.88	0.61	347.15	122.12	38.90	25.83	12.31	3.47	3.85	5.11
T_2- Soil application $MgSO_4$ @ 40 kg ha^{-1}	5.60	0.65	350.57	137.20	32.91	28.66	12.85	3.68	3.88	5.21
T_3- Soil application $MgSO_4$ @ 60 kg ha^{-1}	5.41	0.74	352.17	151.33	36.00	29.12	13.30	3.82	3.88	5.23
T_4- Soil application $MgSO_4$ @ 80 kg ha^{-1}	5.37	0.71	348.53	162.11	42.43	29.67	14.06	4.05	3.97	5.32
T_5- Soil application $MgSO_4$ @ 120 kg ha^{-1}	5.33	0.88	351.41	174.79	46.53	31.70	14.98	4.96	3.97	5.35
T_6- Control	5.86	0.75	326.45	81.34	23.01	24.24	11.70	3.30	3.76	5.02
LSD (0.05)	**0.12**	**0.14**	**10.66**	**14.52**	**7.06**	**2.56**	**1.24**	**0.40**	**NS**	**NS**

Table 5: Effect of different levels of B on soil chemical properties and availability of secondary and micronutrients in the cardamom plantation (pooled mean of 2018 and 2019)

Treatments	pH	EC dS m^{-1}	Available Ca	Available Mg	Available S	Available Fe	Available Mn	Available Zn	Available Cu	Available B
						mg kg^{-1}				
T_1- Soil application Borax @ 0.5 kg ha^{-1}	5.84	0.35	324.45	123.77	12.32	27.26	12.22	3.83	3.79	5.61
T_2- Soil application Borax @ 1.0 kg ha^{-1}	5.80	0.36	328.29	123.41	12.87	28.82	12.89	3.83	4.01	5.91
T_3- Soil application Borax @ 1.5 kg ha^{-1}	5.75	0.40	332.35	124.42	13.41	29.31	14.42	3.87	4.18	6.98
T_4- Soil application Borax @ 2.0 kg ha^{-1}	5.67	0.42	346.24	124.81	13.55	30.97	14.89	4.11	4.28	7.21
T_5- Foliar application Borax @ 0.2 %	5.97	0.45	346.56	123.35	14.11	31.98	15.79	4.21	4.30	4.11
T_6- Control	6.06	0.37	320.71	122.97	13.11	24.16	10.54	3.82	3.69	2.41
LSD (0.05)	**0.27**	**NS**	**18.25**	**NS**	**NS**	**4.45**	**2.84**	**NS**	**0.40**	**0.80**

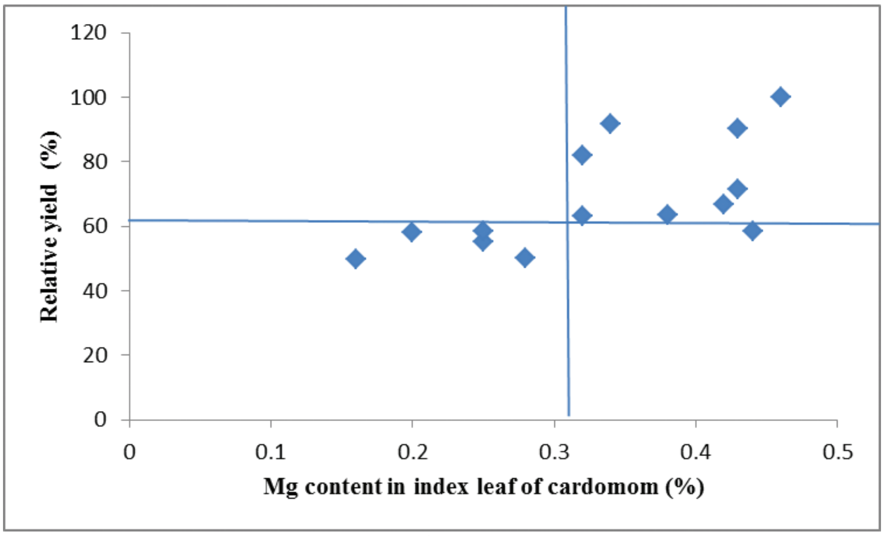

Fig. 1 :

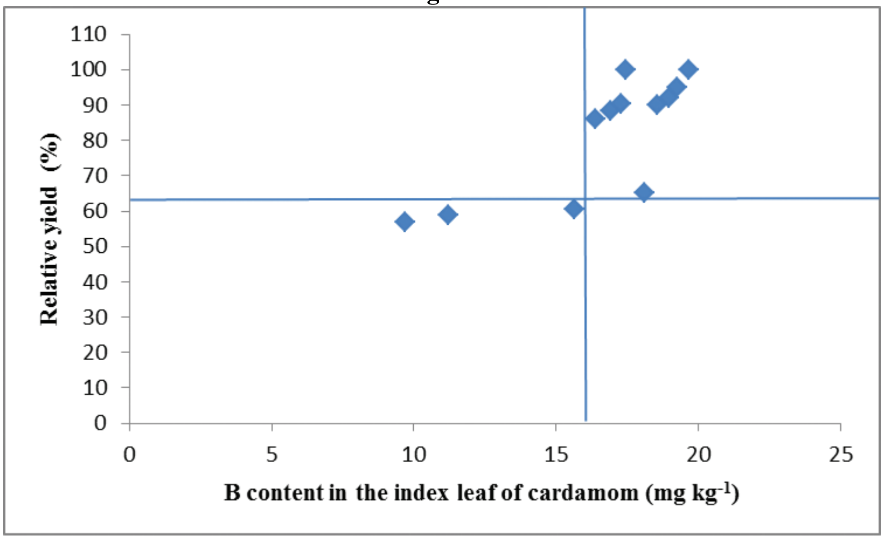

Fig. 2 :

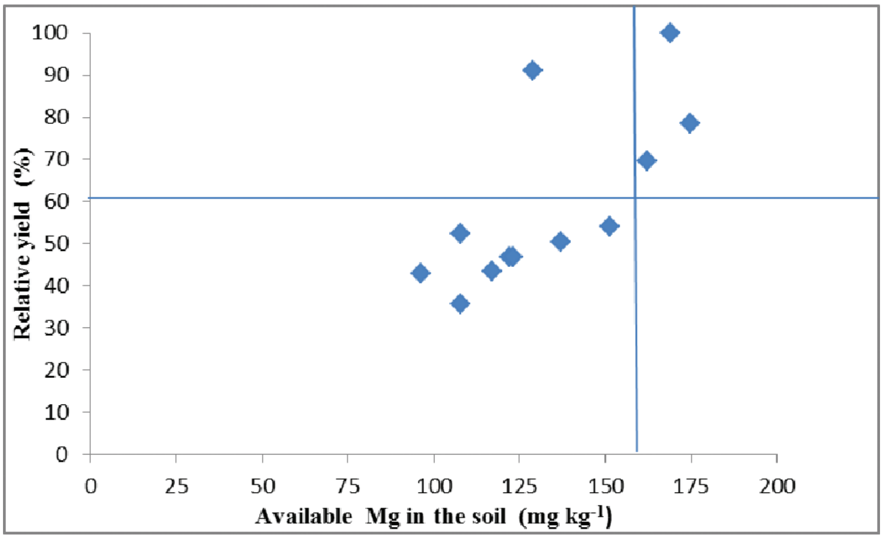

Fig. 3: Critical limit of available Mg in the soil of cardamom plantation

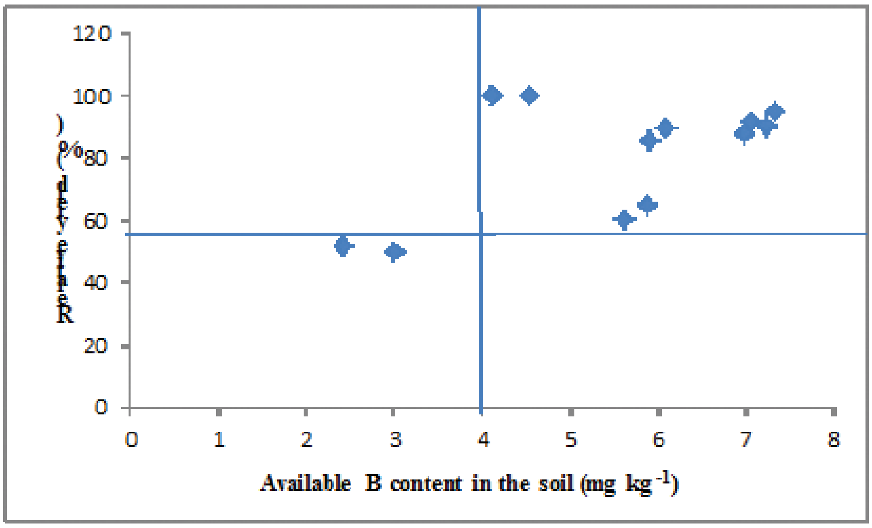

Fig. 4: Critical limit of available B in the soil of cardamom plantation

enhance the crop yield. Application of $MgSO_4$ @ 120 kg ha^{-1} has resulted in better growth and more nutrient uptake. When the deficiency of B was ameliorated by the foliar application, uptake of other nutrients also increased as compared to other treatments. It indicates that foliar application of B is more beneficial than its soil application. Also dosage of B required for foliar application of B is much less than that is needed for soil application.

Effect of treatments on cardamom yield

In Mg experiment conducted in cardamom plantation, a significantly higher yield (5.49 kg plant^{-1}) was obtained from the treatment which received Mg @ 120 kg ha^{-1} (Table 2). Here, cardamom yield increased 1.84 times than that of control. Wang *et al*. (2020) reported that application of Mg has increased crop yield by 8.5 % and enhanced agronomic efficiency to 34.4 kg kg^{-1}. Similarly, there are reports that amelioration of Mg deficiency had enhanced tomato yield by 12.5 % (Kashinath *et al.,* 2013) and grain yield in barley by 8.6 % (Mahdi *et al*., 2012).

In B experiment conducted in cardamom plantation, a significantly higher yield (5.24 kg plant^{-1}) was obtained from the treatment which received foliar application of borax @ 0.2 % (Table 3). Foliar application of B has increased cardamom yield 1.75 times than that of control. Foliar application of B has more efficiency than soil application (Al-Obeed *et al*., 2018; Shireen *et al*., 2018). Soil application of B can cause leaching loss. The recovery percentage of B is more in foliar application than soil application.

Effect of treatments on secondary and micronutrients availability in the soil

The availability of secondary and micronutrients such as Ca (351.41 mg kg^{-1}), Mg (174.79 mg kg^{-1}), S (46.53 mg kg^{-1}), Fe (31.70 mg kg^{-1}), Mn (14.98 mg kg^{-1}), Zn (4.96 mg kg^{-1}), Cu (3.97 mg kg^{-1}) and B (5.35 mg kg^{-1}) were comparatively higher in treatment which received $MgSO_4$ @ 120 kg ha^{-1} (Table 4).

Similarly availability of all the nutrients such as Ca (346.56 mg kg^{-1}), Mg (123.35 mg kg^{-1}), S (14.11 mg kg^{-1}), Fe (31.98 mg kg^{-1}), Mn (15.79 mg kg^{-1}), Zn (4.21 mg kg^{-1}), Cu (4.30 mg kg^{-1}) and B (4.11 mg kg^{-1}) were comparatively higher in treatment which received foliar application of borax @ 0.2 % (Table 5).

Enhanced growth of crop plants under optimum nutrient balance caused more nutrient mining and thus enhanced the nutrient availability in the soil. The foliar fertilization can stimulate availability and uptake of soil applied fertilizers and thus can result in more yield. Similar results regarding the enhanced nutrient availability in the soil due to the fertigation with N, P and K nutrients were reported by Murthy *et al*. (2020).

Critical concentration of Mg and B in soil and plant

Critical nutrient concentration is the nutrient concentration below which nutrient deficiency symptoms are noticed in the plants. Critical level of Mg in the index leaf of cardamom was found to 0.31 % and that of B was 16 mg kg^{-1} (Fig. 1 and 2). The critical limit of available Mg in soil was delineated as 160 mg kg^{-1} and boron as 4 mg kg^{-1} (Fig. 3 and 4). So the nutrients Mg and B have to be given at dosage to maintain their concentration above the critical level in soil and plant tissue.

CONCLUSION

In cardamom plantations of Idukki district which are deficient in Mg and B, the deficiency can be ameliorated and maximum potential yield can be obtained by providing Mg as $MgSO_4$ @ 120 kg ha^{-1} and B as foliar application of borax @ 0.2 %. At this dosage, the nutrient concentration of these nutrients is maintained above their critical concentration in soil and plant.

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