Korean J. Soil Sci. Fert. **36**(4), 218-224(2003)

Article

Effect of Mg-Sulfate and Mg-Hydroxide on Growth of Chinese Cabbage

Sang-Jo Lee, Sung-Ho Lee, Hyun-Jin Shin, Hyun-Jong Cho[1], Bok-Jin Kim and Jong-Bae Chung[1]*

Dept. of Agronomy, Yeungnam University, Gyeongsan 712-749, Korea
[1]Dept. of Agricultural Chemistry, Daegu University, Gyeongsan 712-714, Korea

Magnesium hydroxide, which recently registered as a Mg fertilizer, is greatly different from magnesium sulfate in its solubility and effect on soil pH. In this study, the effects of magnesium hydroxide and magnesium sulfate on growth of chinese cabbage were compared at the application rate of 300 kg MgO ha^{-1} in a Gyeongsan clay loam soil. Although magnesium hydroxide was effective in increasing number of leaf and fresh weight, overall effects of magnesium hydroxide and magnesium sulfate on the growth of chinese cabbage were not significantly different ($p \leq 0.05$). Comparing the two magnesium fertilizer treatments, magnesium content of chinese cabbage was relatively higher in the magnesium sulfate treatment in the early stage of growth, but it was higher in the magnesium hydroxide treatment at harvest. Contents of Ca, P, and K in chinese cabbage were relatively higher in the magnesium hydroxide treatment than those in magnesium sulfate treatment. But, the differences in nutrient uptakes by chinese cabbage between the treatments were not significant ($p \leq 0.05$). Therefore, magnesium hydroxide is expected to be used with nearly the same effects on crops as magnesium sulfate at the same application rate of Mg. Soil pH in the treatment of magnesium sulfate was lower than that of control treatment, but magnesium hydroxide could increase pH. Magnesium hydroxide can be used preferentially in acid and/or sandy soils, where magnesium sulfate can induce further soil acidification and leaching loss of Mg is often a severe problem.

Key words : Chinese cabbage, Magnesium fertilizer, Magnesium hydroxide, Magnesium sulfate.

Introduction

Magnesium is one of the essential inorganic macronutrients in plants. A major function of Mg is its role as the central atom of the chlorophyll molecule and when the supply of Mg is optimal for growth, between 10 and 20% of the total Mg of leaves is localized in the chloroplasts (McSwain, 1982). High concentration of Mg is required in the chloroplasts and cytoplasm to maintain a high pH between 6.5 and 7.5. The influence of pH on protein structure and hence enzyme activity is dependent on the strict regulation of the pH of the metabolic pool, and cations such as Mg and K mostly perform this regulatory function (Smith and Raven, 1979). Magnesium also has an essential function as a bridging element for the aggregation of ribosome

Received : July 1. 2003 Accepted : July 21. 2003
*Corresponding author: Phone : +82538506755, Fax: +82538506759, E-mail : jbchung@daegu.ac.kr

subunits, a process that is necessary for protein synthesis (Cammarano et al., 1972). Magnesium is also required for RNA polymerases and hence for the formation of RNA in the nucleus. There is a long list of enzyme reactions that require or are promoted by Mg. Reactions such as the transfer of phosphate (phosphatases and ATPases) or of carboxyl groups (carboxylase) require Mg (Marschner, 1986).

Magnesium is generally taken up by plants in lower quantities than Ca or K. The contents of Mg in plant tissues are usually in the order of 0.5% of the dry matter. Cation competitive effects in uptake are of particular importance for Mg as such effects frequently lead to Mg deficiency in the field, and deficiencies occur particular in highly leached acid soils or on sandy soils which have been given heavy dressing of lime (Tisdale et al., 1985). Although Mg deficiency symptom differ between plant species, intervenial yellowing or chlorosis occurs and in extreme cases the area become necrotic.

In the Official Standard of Fertilizers in Korea, magnesium hydroxide, magnesium sulfate, caustic-calcined magnesia, and magnesium borate are listed as a Mg fertilizer. Potassium magnesium sulfate, dolomitic limestone, and silica fertilizers also contain Mg. In Japan, magnesium hydroxide is listed in Official Standards of Fertilizers, and a large amount of this Mg fertilizer is consumed. In our country, magnesium hydroxide was registered on the Official Standard of Fertilizers in 2002, and still is not widely used in the fields.

Magnesium sulfate and magnesium hydroxide are different in their chemical properties including solubility, and then the effects of these Mg fertilizers on soil chemical properties, pH, EC and distribution of Mg and other exchangeable cations in soi,l can be much different. Lee et al. (2003) found that soil pH was increased and Mg release from the fertilizer was slow and also the effects of applied Mg on the other cation distributions were not significant in soil treated with magnesium hydroxide as compared with magnesium sulfate treatment. Therefore the effects of these Mg fertilizers on plant growth should be carefully examined and compared.

In this study, the effects of magnesium hydroxide and magnesium sulfate on the growth of chinese cabbage and soil properties were investigated.

Materials and Methods

Plant and soil Field plots for the experiment were established in the March 2001 on a soil of Gyeongsan series (fine silty, mixed, mesic Fluvaquentic Eutrochrepts) at the experimental farm of Youngnam University. Soil properties are presented in Table 1. 'Maeryuk' chinese cabbage (*Brassica pekinensis* Rupr.) was the crop tested in this experiment.

Fertilizer treatments Fertilizer magnesium hydroxide ($Mg(OH)_2$) was provided from FOSREC Co. and fertilizer magnesium sulfate ($MgSO_4$) was purchased from Geondo Co. in

Table 1. Physicochemical properties of the soil used in this study.

Texture	pH (1:5)	OM	T-N	Av. P_2O_5	CEC	Exchangeable cation			
						Ca	Mg	K	Na
		-------- g kg^{-1} --------		mg kg^{-1}	---------- cmol$_c$ kg^{-1} ----------				
clay-loam	5.42	20.6	1.2	113.1	11.2	4.2	1.9	0.9	0.6

Pohang. Magnesium content in the fertilizers was 140 and 600 g MgO kg^{-1} for magnesium sulfate and magnesium hydroxide, respectively. Magnesium sulfate is completely water soluble, and the solubility of magnesium hydroxide in water is 1.9 mg L^{-1} at 18℃.

Rate of 300 kg MgO ha^{-1} was applied 5 days before transplanting of chinese cabbage with magnesium sulfate and magnesium hydroxide. Nitrogen, P, K, and B were applied using urea, fused phosphate, potassium chloride, and borax at the rate of 230, 160, 250, and 15 kg ha^{-1} for N, P_2O_5, K_2O, and B_2O_3, respectively. Phosphorus, K, and B fertilizers were all applied 5 days before transplanting, and 50% of the N was applied before transplanting and additional 3 split applications of 20-20-10% at every 15 days after transplanting. Control (no Mg application) was also included within a randomized complete block design with three replications. Each plot was 3 m wide by 5 m long, and 20-day-old chinese cabbage seedlings were planted by 60× 35 cm on 18 April 2001.

Measurements and analysis Growth of chinese cabbage was measured at 15, 30, and 45 days after transplanting and at the day of harvest (18 June 2001). Number of leaf, length of the largest leaf, and height, width, and fresh weight of head were included in the measurement. Leaf color was also measured at 15, 30, and 45 days after transplanting using a chlorophyll meter (Minolta SPAD-502, Japan). The means were compared with Duncan's Multiple Range Test (DMRT) at $p \leq 0.05$ level.

Plant samples were taken at 30 days after transplanting and at harvest for inorganic nutrient analysis. Leaves were separated, rinsed with deionized water, and dried at 65℃. Dried leaf samples were digested with H_2SO_4 and H_2O_2 using Kjeltec digesting unit (Foss KT2300, Hoganas, Sweden), and N was determined using Kjeldahl distillation system (Foss Kjeltec System 1026, Hoganas, Sweden). Phosphorus was determined using vanadomolybdate method. Potassium, Ca, and Mg were determined by ICP emission spectrometer (Varian Liberty Series II, Mulgrave, Austria).

Soil samples were collected at 30 days after transplanting and at harvest, and air-dried and ground <2 mm. pH was measured in 1:5 water suspension using a combination glass electrode (Mettler 350, Mettler-Toledo Ltd., Essex, England). Organic matter, total N, and available P in the soil samples were measured by Walkley-Black method, Kjeldahl method, and Bray No. 1 method, respectively (Nelson and Sommers, 1982; Bremner and Mulvaney, 1982; Olsen and Sommers, 1982). Analysis of 1 M KCl extractable Ca, Mg, and K was performed using ICP emission spectrometer (Varian Liberty Series II, Mulgrave, Australia).

Results and Discussion

Growth of chinese cabbage Results of the measurement of leaf color, length of the largest leaf, and number of leaf during the growth are reported in Table 2. The SPAD values were higher in Mg fertilizer treatment compared with the no Mg control treatment, but the difference was not significant. Length of the largest leaf and number of leaf were also higher in Mg fertilizer treatment compared with the no Mg control treatment, but the difference was not significant. There was no significant difference in the growth of chinese cabbage between the treatments of magnesium sulfate and magnesium hydroxide.

Yield and yield parameters of chinese cabbage are presented in Table 3. Head height was higher in the magnesium hydroxide treatment than in the

Table 2. Effect of magnesium fertilizer treatments on leaf color, length of the largest leaf, and number of leaf of chinese cabbage at various growing stages.

Measurement	Treatment	Days after transplanting		
		15	30	45
Leaf color (SPAD)	No Mg	34.49	50.01	44.96
	$MgSO_4$	34.96	51.44	47.45
	$Mg(OH)_2$	35.07	50.64	46.82
Length of the largest leaf (cm)	No Mg	8.33	23.13	33.46
	$MgSO_4$	9.58	24.07	34.69
	$Mg(OH)_2$	9.69	23.82	34.94
Number of leaf	No Mg	8.11	16.17	45.78
	$MgSO_4$	8.44	16.89	49.89
	$Mg(OH)_2$	8.75	16.42	48.78

Table 3. Effect of magnesium fertilizer treatments on fresh weight, height, and width of head and number of leaf of chinese cabbage at harvest.

Treatment	Fresh wt. of head	Height of Head	Width of head	Number of leaf
	g	cm	cm	$palnt^{-1}$
No Mg	1,950 a	24.5 ns	14.3 ns	68.8 a
$MgSO_4$	2,040 a	24.1	14.7	72.0 b
$Mg(OH)_2$	2,200 b	25.6	14.9	71.1 b

control treatment (no Mg). But the differences of head height among the three treatments were not significant ($p \leq 0.05$). Head width was also increased with Mg treatment, and the differences of head height among the three treatments were not significant ($p \leq 0.05$). Number of leaf was significantly higher in the treatments of Mg than in the control, but the difference was not significant between the treatments of magnesium sulfate and magnesium hydroxide. Fresh weight of chinese cabbage was significantly higher in the treatment of magnesium hydroxide compared with the control and magnesium sulfate treatments.

Nutrient uptake Nutrient uptakes of chinese cabbage are presented in Table 4. At 30 days after transplanting, Mg content was relatively higher in the treatments of Mg fertilizers. And N and P contents were also higher in the treatments of Mg fertilizers compared with the no Mg treatment. However, contents of Ca and K were relatively lower in the treatments of Mg fertilizers. At harvest, the nutrient contents were also not significantly different among the treatments, but Mg content were higher and Ca and K contents were lower in the treatments of Mg fertilizer in comparison to the no Mg treatment.

The lower contents of Ca and K in chinese cabbage could be due to the competition of Mg and Ca or K in the nutrient uptake. And also Mg added by the fertilizers could replace Ca and/or K from exchange sites and enhanced leaching losses of those elements could be another reason for the lower contents of Ca and K in chinese cabbage. However, the differences in nutrient uptakes by chinese cabbage among the treatments were not significant ($p \leq 0.05$).

Table 4. Effect of magnesium fertilizer treatments on inorganic nutrient contents of chinese cabbage at 30 days after transplanting and at harvest.

Sampling time	Treatment	T-N	P_2O_5	CaO	K_2O	MgO
		------------	------------	g kg^{-1} dry weight	------------	------------
30 days after transplanting	No Mg	45.3	17.1	42.5	94.2	6.8
	$MgSO_4$	46.8	18.0	40.7	89.7	7.9
	$Mg(OH)_2$	45.7	17.9	41.5	92.2	7.6
Harvest	No Mg	36.7	21.5	43.7	85.7	6.0
	$MgSO_4$	39.3	22.0	40.8	82.7	8.4
	$Mg(OH)_2$	37.4	22.4	41.0	84.1	9.3

Comparing the two Mg fertilizer treatments, Mg content in chinese cabbage was higher in the magnesium sulfate treatment at early stage of growth, but the content was higher in the magnesium hydroxide treatment at harvest. This result could be attributed to the difference in solubility of the two Mg fertilizers and suggests that magnesium hydroxide can supply Mg slowly and continuously during the growth period.

Contents of Ca, P, and K in chinese cabbage, comparing the two Mg fertilizer treatments, were relatively higher in the magnesium hydroxide treatment. Such differences in inorganic nutrient uptake could be due to the competitions among cations in uptake by plant and adsorption /desorption in soil. And these cation behaviors in soil can be influenced by the applied Mg, and the effects of Mg on the behavior of other cations could be much greater in the soil of magnesium sulfate treatment, since magnesium sulfate is completely water soluble. Magnesium sulfate can release relatively large amount of Mg shortly after application in soil.

The effect of Mg fertilizers on P uptake would be related to the effects of the fertilizer on soil pH. And also SO_4 released from magnesium sulfate could inhibit P uptake by chinese cabbage. However, still the differences in nutrient uptake between the two Mg fertilizer treatments were not significantly different ($p \leq 0.05$).

Soil properties Soil properties measured at 30 days after transplanting and at harvest are presented in Table 5. Soil pH in the treatment of magnesium sulfate was lower than that of control treatment. But, compared with the control treatment, magnesium hydroxide treatment could increase soil pH.

Total N and organic matter contents were not significantly different among the treatments. Available P content in soil was higher in the treatment of magnesium hydroxide in comparison to the magnesium sulfate treatment. The reason for the higher available P content in the magnesium hydroxide treatment could be, in some extent, attributed to the increase of soil pH. Availability of P in soil is very sensitive to pH condition. As soil pH increase, decrease of the solubility of Al and Mn can be followed by increase of the availability of P (Longnecker and Merkle, 1952).

At 30 days after transplanting and at harvest, 1 M KCl extractable Mg content in soil was much higher in the Mg treatments comparing to the control. Extractable Ca content in soil was significantly lowered in the treatment of magnesium sulfate. Since magnesium sulfate is water soluble, introducing of a large amount of Mg in soil with magnesium sulfate application can effectively compete with Ca in cation adsorption in soil (Lee et al., 2003). Comparing

Table 5. Effect of magnesium fertilizer treatments on soil properties measured at 30 days after transplanting and at harvest.

Sampling time	Treatment	pH (1:5)	T-N	OM	Av. P_2O_5	Extractable cation Ca	Mg	K
			------- g kg^{-1} -------		mg kg^{-1}	------------ $cmol_c$ kg^{-1} ------------		
30 days after transplanting	No Mg	4.89	1.28	24.4	107.2	4.38	1.57	0.96
	$MgSO_4$	4.85	1.36	23.8	112.6	4.02	2.46	0.93
	$Mg(OH)_2$	5.20	1.35	23.2	125.1	4.42	2.21	0.99
Harvest	No Mg	5.20	1.29	22.9	126.8	4.21	1.86	0.95
	$MgSO_4$	4.97	1.33	21.8	124.0	3.90	2.31	0.92
	$Mg(OH)_2$	5.69	1.31	20.6	145.5	4.34	2.56	0.96

the two Mg fertilizer treatments, extractable Mg content was higher in the magnesium sulfate treatment at 30 days after transplanting, but it was higher in the magnesium hydroxide treatment at harvest. The leaching loss of Mg in the magnesium sulfate treatment could be much higher compared with the magnesium hydroxide treatment. However, extractable K content was not significantly affected by Mg treatment. The less exchange removal of K in the soil may be due to the relatively lower content of extractable K content in soil and also to the selectivity of K over Mg in binary exchange adsorption process (Jensen and Bobcock, 1973).

Conclusions

Although magnesium hydroxide was effective in increasing number of leaf and fresh weight of chinese cabbage, overall effects of magnesium hydroxide and magnesium sulfate on the growth of chinese cabbage were found not to be significantly different ($p \leq 0.05$). Therefore magnesium hydroxide, recently registered as a Mg fertilizer, can be used with nearly the same effects on crops as magnesium sulfate at the same application rate of Mg.

Continuous application of magnesium sulfate can induce acidification and salt accumulation of soil. And also leaching loss of Mg could be high when water-soluble magnesium sulfate is applied in sandy soils. However, magnesium hydroxide is an alkali fertilizer and less soluble, and therefore continuous slow supply of Mg and less adverse effects on other cation uptake and distributions in soil would be advantages of magnesium hydroxide over magnesium sulfate. Magnesium hydroxide could be used preferentially in acid and/or sandy soils.

References

Bower, C.A., G. Ogata, and J.M. Tucker. 1968. Sodium hazard of irrigation waters as influenced by leaching fraction and by precipitation or solution of calcium carbonate. Soil Sci. 106:29-34.

Bremner, J.M., and C.S. Mulvaney. 1982. Nitrogen-Total. p. 595-624. In A.L. Page et al. (ed.) Methods of soil analysis, Part 2. Chemical and microbiological properties (2nd ed.). Soil Science Society of America, Madison, Wisconsin, USA.

Cammarano, P., A. Felsani, M. Gentile, C. Gualerzi, C. Romeo, and G. Wolf. 1972. Formation of active hybrid 80-S particles from subunits of pea seedlings and mammalian liver ribosomes. Biochim. Biophys. Acta 281:625-642.

Jensen, H.E., and K.L. Bobcock. 1973. Cation exchange equilibria on a Yolo loam. Hilgardia 41:475-487.

Lee, S.J., S.H. Lee, H.J. Shin, H.J. Cho, B.J. Kim, and J.B. Chung. 2003. Comparison of the effects of Mg-sulfate and Mg-hydroxide on soil pH, EC and exchangeable cation

distribution. Korean J. Soil Sci. Fert. 36:105-112.
Longnecker, D., and F.G. Merkle. 1952. Influence of placement of lime compounds on root development and soil characteristics. Soil Sci. 73:71-74.
Marschner, H. 1986. Mineral nutrition of higher plants. Academic Press, London, UK.
McSwain, B.D., H.Y. Tsujimoto, and D.I. Arnon. 1982. Effects of magnesium and chloride ions on light-induced electron transport in membrane fragments from a blue-green alga. Biochim. Biophys. Acta 423:313-322.
Nelson, D.W., and L.E. Sommers. (1982) Total carbon, organic carbon, and organic matter. p. 539-579. In A.L. Page et al. (ed.) Methods of soil analysis, Part 2. Chemical and microbiological properties (2nd ed.). Soil Science Society of America, Madison, Wisconsin, USA.
Olsen, S.R., and L.E. Sommers. 1982. Phosphorus. p. 403-430. In A.L. Page et al. (ed.) Methods of soil analysis, Part 2. Chemical and microbiological properties (2nd ed.). Soil Science Society of America, Madison, Wisconsin, USA.
Pratt, P.F., and F.L. Bair. 1969. Sodium hazard of bicarbonate irrigation water. Soil Sci. Soc. Amer. Proc. 33:880-883.
Thomas, G.W. 1982. Exchangeable cations. p. 73-126. In A.L. Page et al. (ed.) Methods of soil analysis, Part 2. Chemical and microbiological properties (2nd ed.). Soil Science Society of America, Madison, Wisconsin, USA.
Tisdale, S.L., W.L. Nelson, and J.D. Beaton. 1985. Soil fertility and fertilizers. Macmillan Publishing Co., New York, USA.
Van Lierop, W. 1990. Soil pH and lime requirement determination. p. 73-126. In R.L. Westerman et al. (ed.) Soil testing and plant analysis. Soil Science Society of America, Madison, Wisconsin, USA.

배추에 대한 황산고토와 수산화고토의 비효 비교

이상조 · 이승호 · 신현진 · 조현종[1] · 김복진 · 정종배[1]
영남대학교 생물자원학부, [1]대구대학교 생명환경학부

최근 고토비료로 등록된 수산화고토는 황산고토와 비교할 때 용해도가 매우 낮으며 토양반응에 미치는 영향 측면에서도 다른 특성을 가지고 있다. 본 연구에서는 이들 두 가지 고토비료를 표준시비량인 300 kg MgO ha^{-1} 수준으로 처리한 경산통 토양에서 배추 재배하여 그 비효를 비교하였다. 수산화고토는 배추의 엽수와 생체중을 증가시키는 효과를 보였으나, 생육 전반에 미치는 효과에 있어서는 황산고토와 비교할 때 통계적으로 유의성 있는 차이를 보이지는 않았다 ($p \leq 0.05$). 배추의 마그네슘 함량은 생육초기에는 황산고토 처리구에서 높았으나 수확기에 조사된 결과에서는 수산화고토 처리구에서 높았으며, Ca, P, 및 K 함량은 황산고토에 비하여 수산화고토 처리구에서 높았다. 그러나 비종간의 이들 양분 흡수의 차이는 통계적으로 유의하지 못하였다. 황산고토를 처리한 토양의 pH는 대조구에 비하여 낮아졌으나, 수산화고토 처리구에서는 pH가 높아졌고 유효인산 함량 또한 증가하였다. 침출성 Ca 함량은 수산화고토 처리구에 비하여 황산고토 처리구에서 낮게 나타났다. 토양반응과 양분의 유효도에 미치는 영향의 차이는 비종간의 화학적 특성 차이에 기인하는 것으로 판단된다. 따라서 동일한 수준으로 시용할 때, 수산화고토와 황산고토의 작물에 대한 비효는 대등한 것으로 결론지을 수 있으며, 산성토양이나 용탈이 쉽게 일어날 수 있는 사질 토양에서는 산성비료이며 수용성인 황산고토보다 수산화고토의 시용이 유리할 것으로 판단된다.