An Interaction between Magnesium and Calcium in Cabbage-Nutrition

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Summary

Cabbage plants were water-cultured under a combination of 4 levels of magnesium (0, 5, 25, 125 ppm) and calcium (4, 20, 100, 500 ppm), and the effect of the elements supplied on the growth and nutrient status of the plants was studied.

The dry weight of a whole plant (plant—top+roots) and inner leaves increased with increasing levels of Mg from 0 to 125 ppm when the concentration of Ca in the culture solution was high, whereas it decreased at higher levels of Mg when the concentration of Ca was low. The contents of Mg and Ca in the plants increased with increasing levels of each element, and an increase in the content of one element caused a decrease in the content of the other element. The plants high in Mg or Ca were liable to suffer from deficiency injury involving Ca or Mg. The critical contents of Mg and Ca in outer leaves resulting in deficiency injury were about 0.1 and 1.3% on a dry matter basis, respectively.

A suitable range of the Ca/Mg content ratio as well as adequate contents of Mg and Ca in each organ is considered to be favorable for the growth of cabbage plants.

Introduction

Magnesium and calcium are recognized to be essential for the growth of higher plants. The critical contents of the elements in plants leading to deficiency injury have been evaluated in many crops, and their roles in plant-tissues are being clarified through many studies. The excess injury by magnesium in crops, on the other hand, has also been studied(2). Magnesium is not called an alkaline earth metal but calcium. They are divalent cations. There is abundant evidence that divalent cations compete with each other in the uptake by higher plants, and the competition between magnesium and calcium is generally considered as an antagonistic interaction.

To reconfirm the information, the present experiment was aimed at studying the combined effect of graded levels of both magnesium and calcium in a culture solution on the growth and nutrient status of cabbage plants. In connection with this, the results of the

intracellular distribution of magnesium and calcium in the cabbage leaves have already been presented in the preceding report (1).

Materials and Methods

On April 14, 1973, seeds of a Nagaoka cabbage variety, Soshu, were sown in vermiculite with tap-water and grown in a green house. On May 3, the seedlings were transferred into 4 liter-pots, with three seedlings per pot, containing a standard culture solution prepared with demineralized water and Wako Co. chemicals (1). The composition of the culture solution, in mg/l, was : 50N, 20P, 50 K, 100 Ca, 50 Mg, 2 Fe, 1 B, 0.5 Mn, 0.2 Zn, 0.05 Cu, and 0.05 Mo. Their chemical forms were NaNO_3 , Na_2HPO_4 , K_2SO_4 , CaCl_2 , MgSO_4 , FeSO_4 , H_3BO_3 , MnSO_4 , ZnSO_4 , CuSO_4 , and Na_2MoO_4 , respectively. The culture solution was aerated at one hour intervals and renewed once a week, and its pH was adjusted to be 5 with 1 N- H_2SO_4 or 1 N- NaOH . Two seedlings per pot had been thinned until May 20. On May 27, the plants were imposed upon 16 treatments combined with 4 levels of magnesium (0, 5, 25, 125 ppm) and calcium (4, 20, 100,

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500 ppm), which were added as MgSO_4 and CaCl_2 to the culture solution in two replications.

At harvest, August 2, the plants were separated into inner leaves (which were composed of a cabbage-head), outer leaves (which were not part of the cabbage-head), stems (which were deprived of all the leaves), and roots. After the roots were washed with demineralized water, all the organs were dried at 70°C for 3 days, weighed, and milled for chemical analysis. But the plants at 125 ppm Mg and 4 ppm Ca were sampled on June 28 when they were almost dead.

After digestion of the plant-samples with the sulfuric-nitric-perchloric acid mixture, magnesium and calcium were determined by the atomic absorption method with a Hitachi Model 208 spectrophotometer.

Results and Discussion

The dry weight of a whole plant (plant+top+roots) and inner leaves increased with increasing levels of magnesium from 0 to 125 ppm when the concentration of calcium in the culture solution was high, whereas it decreased at high levels of magnesium when the concentration of calcium was low (Table 1). Symptoms of the deficiency injury by

magnesium were observed in all the plots at 0 ppm Mg except the plot at 0 ppm Mg and 4 ppm Ca: Yellow-brown speckles appeared along the edges of the outer leaves which looked chlorotic in spots. The severe deficiency injury by calcium occurred in all the plots at 4 ppm Ca and slight injury in all the plots at 20 ppm Ca except the plot at 25 ppm Mg and 20 ppm Ca, and the symptoms were characterized by the abnormal expansion of the young leaves with breakages at their marginal parts and by the subsequent development of necrosis between leaf-veins of the deformed leaves which felt very stiff.

The inner leaves/whole plant ratio decreased when the plants were deficient in magnesium or calcium (Table 1). This decrease brings about a loss in commercial values of cabbage plants, because the inner leaves are the main part to be eaten among cabbage-organs.

Tables 2 and 3 show the results of the contents of magnesium and calcium in the plants. As the concentration of magnesium in the culture solution increased, the content of magnesium in each organ increased and the content of calcium decreased. As the concentration of calcium increased, the content of magnesium decreased and the content of calcium increased. That is, such tendencies were

Table 1 Dry weight of a whole plant and inner leaves, and the inner leaves/whole plant ratio

Treatments		Plot No.	Whole plant (g/plant) a	Inner leaves (g/plant) b	b/a
Mg	Ca				
(ppm)					
0	4	1	18.2	2.2	0.12
0	20	2	28.5	7.4	0.26
0	100	3	56.3	20.3	0.36
0	500	4	54.4	19.0	0.35
5	4	5	26.2	9.2	0.35
5	20	6	37.1	12.2	0.33
5	100	7	79.1	38.0	0.48
5	500	8	67.6	29.1	0.43
25	4	9	19.0	6.8	0.36
25	20	10	50.3	21.1	0.42
25	100	11	74.6	34.9	0.47
25	500	12	78.0	37.4	0.48
125	4	13	1.5	0.0	—
125	20	14	32.0	9.6	0.30
125	100	15	62.9	28.3	0.45
125	500	16	81.9	36.0	0.44

Table 2 Content of magnesium in several organs (%) on a dry matter basis)

Treatments		Organs			
Mg	Ca	Inner leaves	Outer leaves	Stem	Roots
(ppm)					
0	4	0.16	0.10	0.19	0.41
0	20	0.12	0.07	0.17	0.23
0	100	0.07	0.06	0.10	0.20
0	500	0.05	0.05	0.14	0.15
5	4	0.30	0.40	0.52	0.41
5	20	0.19	0.29	0.47	0.33
5	100	0.12	0.15	0.24	0.26
5	500	0.11	0.13	0.20	0.15
25	4	0.42	1.78	0.80	0.63
25	20	0.32	1.25	0.67	0.62
25	100	0.16	0.49	0.37	0.37
25	500	0.12	0.22	0.23	0.36
125	4	—	2.20	1.28	0.92
125	20	0.57	2.05	1.08	0.88
125	100	0.23	1.01	0.65	0.44
125	500	0.15	0.40	0.37	0.44

Table 3 Content of calcium in several organs (% on a dry matter basis)

Treatments		Organs			
Mg	Ca	Inner leaves	Outer leaves	Stem	Roots
(ppm)					
0	4	0.39	1.04	0.39	0.44
0	20	0.51	1.38	0.56	0.53
0	100	0.57	2.15	0.61	0.70
0	500	0.70	2.20	0.63	0.74
5	4	0.40	1.04	0.34	0.44
5	20	0.49	1.42	0.48	0.50
5	100	0.57	2.50	0.62	0.68
5	500	0.61	2.81	0.64	0.73
25	4	0.34	0.65	0.31	0.38
25	20	0.45	1.43	0.42	0.45
25	100	0.50	2.49	0.55	0.64
25	500	0.54	2.62	0.56	0.66
125	4	—	0.40	0.28	0.30
125	20	0.23	1.00	0.37	0.32
125	100	0.40	1.55	0.41	0.53
125	500	0.47	2.46	0.53	0.52

found as an increase in the content of magnesium being accompanied with a decrease in the content of calcium, and *visé versa*

As there was an antagonistic interaction between the magnesium and calcium uptake by cabbage plants, the ratio of the content of calcium to that of magnesium in the plants (Ca/Mg ratio) was taken into consideration in drawing a figure of relationship between the relative values of the dry weight of a whole plant and the contents of magnesium and calcium in outer leaves. The relative values were computed as the percentage of the dry weight of each plot to that of the plot at 125 ppm Mg and 500 ppm Ca in which the plants had the highest dry weight. As long as the plots having a Ca/Mg ratio below 5 in the case of the dry weight-Mg content relationship and above 20 in the dry weight-Ca content relationship are excluded, correlation lines can be drawn as in Fig.1. This figure indicates that the critical contents of magnesium and calcium in outer leaves which cause a decrease in the dry weight due to deficiency injury are about 0.1 and 1.3% on a dry matter basis, respectively. Cabbage plants are reported to have the highest requirement for calcium among many crops (4), and from this result, are considered to require more calcium than

Fig. 1 Relationship between the relative values of the dry weight of a whole plant and the contents of magnesium and calcium in outer leaves. The numbers in the figure indicate the same plot No. as shown in Table 1

magnesium. It is apparent that the plants at 0 ppm Mg and 100 ppm Ca, 0 ppm Mg and 500 ppm Ca, and 5 ppm Mg and 500 ppm Ca were suffering from the deficiency injury by magnesium, and that the plants at 25 ppm Mg and 4 ppm Ca, 125 ppm Mg and 4 ppm Ca, and 125 ppm Mg and 20 ppm Ca were suffering from the deficiency injury by calcium. It is worthy of note, however, that the plants in these plots seem to have suffered not only from the deficiency injury by each element but also from a kind of excess injury by calcium or magnesium. This is understandable from the fact that the Ca/Mg ratio of these plants was very high or low. Therefore, a suitable range of the Ca/Mg ratio as well as adequate contents of magnesium and calcium in each organ favors the growth of cabbage plants, and an extraordinary range beyond the range triggers the imbalance in mineral nutrition in the plants which is detrimental to the normal growth. In connection to this, Tanaka *et al.* (3) have reported that the Ca/Mg ratio in corn leaves beyond a certain range caused the reduced growth of the plants, accompanied with a decrease in the photosynthetic rate of their leaves.

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キャベツ栄養におけるマグネシウムとカルシウムの相互作用について

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摘 要

キャベツ (長岡交配早秋) を 4 段階の Mg 濃度 (0, 5, 25, 125 ppm) と Ca 濃度 (4, 20, 100, 500 ppm) の組合わせによる 16 種類の水耕液で栽培し, これら要素供給量がキャベツの生育におよぼす影響を調査した。

全乾物重および球葉の乾物重は水耕液中の Mg 濃度の増加により, 水耕液中の Ca 濃度が高い場合は直線的に上昇し, 低い場合には上昇した後高濃度で低下した。植物体の Mg あるいは Ca 含有率は水耕液中のそれぞれの要素濃度の増加により上昇し, 他方の要素濃度の増加

により低下した。Mg, Ca 含有率が高い植物はそれぞれ Ca, Mg 欠乏障害に陥りやすく, また全乾物重が低下するときの限界 Mg, Ca 含有率は外葉でそれぞれ 0.1, 1.3 % (乾物当り) であった。

これらのことより, キャベツの良好な生育のためには, Mg および Ca 含有率が適当であるばかりでなく, Ca/Mg 含有率比も適当な範囲にあることが望ましいと考えられる。