EFFECT OF FREQUENCY AND RATE OF FOLIAR CALCIUM APPLICATION ON TIPBURN AND HEAD ROT IN CHINESE CABBAGE

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Chinese cabbage *(Brassica pekinensis* Rupr.) is increasing in popularity not only because it is a potential source of income as a cash crop but also due to its high mineral and vitamin content. This crop is sensitive to high temperatures and is usually grown in the highlands. Breeding efforts, which are still going on, have resulted in the production of new hybrids and lines which are adaptable to a wide range of agro-climatic conditions.

In spite of this crop's improvement in heat tolerance and in yield, diseases continue to be its problem. One of its most troublesome diseases is internal tipburn (12). It is a non-parasitic disorder (7), and is a serious problem since the effects remain unknown until the mature head is cut open in the kitchen or in the processing place.

This nutritional disorder seems to be due to calcium (Ca) deficiency (4, 6, 7, 10, 11). It has been definitely shown that marginal tissues of the inner head leaves contain about one third as much Ca (on a dry weight basis) as does the remainder of the head tissue (12). Disorders caused by inadequate level of Ca in affected tissues cannot be corrected merely by supplying additional Ca to the soil (8). However, the use of Ca sprays has been found to prevent the occurrence of blossom end rot (BER) of tomatoes on soils low in Ca and high in soluble salts (9).

Calcium is essential for healthy plant growth. It is a constituent of plant fabrics and regulates the osmotic pressure of the cell sap in order to maintain turgidity (5). Once it goes to the middle lamella of the cell wall, it does not move out. In many crops Ca deficiencies in various organs and tissues are often exaggerated due to the slow rate of mobility in plant tissues, especially under conditions unsuitable for plant growth (1). Symptoms of Ca deficiency will appear usually on the most recently developed tissues since these newly growing parts cannot receive adequate supply of Ca from the older tissues (5). When analyzed, susceptible tissues have been found to have a very low Ca content. Partial to complete control has sometimes been achieved by timely application of this element (11).

Hori *et al.* (4), in their hydroponics experiment, concluded that the appearance of Ca deficiency in Chinese cabbage was due to a decrease in Ca absorption. This decrease was caused by the low Ca level in the medium and partly by the high concentration of salt. It was further pointed out that Ca content of head leaves is rather low even in the normal plant, regardless of high Ca content in the non-wrapper leaves.

It was reported by Chen *et al.* (2) that the growth of head lettuce was not effected by a low Ca level solution. When grown without Ca, leaves developed dark lesions which eventually coalesced to produce general necrosis of the blade (10). Foliar sprays of $Ca(NO_3)_2$ or $CaCl_2$ completely controlled lettuce tipburn (11).

In Brussel sprouts (*Brassica* spp) the incidence of internal browning is related to Ca concentration. Sprout internal browning occured at low Ca levels and decreased as Ca levels were increased (6).

Greenleaf and Adams (3) believed that the blossom end rot (BER) of tomato is cause by Ca deficiency. The phenomena of Ca deficiency were observed by Chen and Uemoto (1) in the third cluster and new unfolded leaves of tomato plants even if $CaCl_2$ was applied.

Maynard *et al.* (7) showed that the degree of Ca accumulation was related to the levels supplied and that this accumulated in the non-wrapper leaves rather than the head leaves. It was discovered that tipburn resistant varieties were more efficient absorbers and accumulators of Ca than the susceptible varieties. This is also true to tomato plants in relation to blossom end rot resistance (3). However, it is generally agreed that tipburn is most severe when both environmental factors and nutritional factors permit periods of very rapid leaf growth (11), especially under conditions of excessive nitrogen fertilization (7). The particular aims of this work were to determine if foliar application of Ca could reduce tipburning and internal breakdown (abnormal shoot development and eventual head rotting) in Chinese cabbage and to define the proper rate and frequency of application.

Materials and Methods

A 3 x 3 factorial field experiment in a randomized complete block design with three replications was conducted in Field No. 31 of AVRDC, Taiwan, ROC from October 13, 1977 to January 5, 1978. Three different amounts of $CaCl_2$ were applied: 0, 3000, and 6000 ppm. Three spraying intervals were used: 10, 15, and 20 days. Plants under O ppm treatment were sprayed with water. The volume of spray was 500 liters per hectare. Each treatment combination was applied to a plot of 24 plants. Fung-Luh, AVRDC Acc. No. 141, a tipburn susceptible cultivar was used.

The land was prepared thoroughly and the seeds were directly sown on a double row bed 1.5 meters wide and 4.8 meters long. Spacing was 50 cm between rows within the bed and 40 cm between heads within rows. Fertilizer was applied at the rate of 200-80-150 kg/ha of N, P_20_5, K_20. Borax and compost were applied at the rate of 10 kg/ha and 10 tons/ha, respectively. All phosphorus, potassium, boron, compost and 40 percent of the nitrogen were incorporated into the soil before sowing. The other nitrogen required was divided into 4 side dressings at 28, 35, 49, and 62 days after sowing (DAS). The plots were mulched with rice straw at the rate of 5 tons/ha to suppress the growth of weeds. Hand weeding was done whenever necessary. The field was kept in good moisture condition by weekly furrow irrigation. Insect pests and diseases were controlled by weekly spraying of Sumicidin 20% EC and Dithane M-45 WP.

The data collected by plot were:

1. Tipburn rating – percent of plants showing symptoms of tipburn.
2. Abnormal shoot development and/or head breakdown (rotting) – percent of plants with such symptoms.
3. Disease rating:
   a) soft rot – percent of plants
   b) TUMV – percent of plants
   c) Downy mildew – none, light, moderate, and severe.
4. Insect damage rating – none, light, moderate, and severe.
5. Yield -- plot yield for total marketable heads and mean head weight.
6. Soil properties of Field No. 31.

Results

No plant exhibited tipburn and head rot symptoms. Thus, no significant variation was observed in the incidence of tipburn, head rot, turnip mosaic virus, downy mildew and soft rot (Tables 3 and 4). Moreover, the marketable yield and mean head weight did not show any significant difference. Insect damage showed significant variation due to $CaCl_2$ spraying interval (Table 4).

Discussion

In spite of the previous experience at AVRDC which revealed that cultivar Fung-Luh is tipburn susceptible, in this trial none of the plants got the disorder.

Takayuki Yoshizawa, Ph.D., soil scientist, AVRDC (personal contact) claims that the environmental conditions during the experimental period were adequate for the optimum uptake and translocation of Ca if soluble Ca is present in the soil. An analysis of the soil shows (Table 1) that the available Ca is relatively high. It should be noted that tipburn is not associated with Ca deficiency in the usual sense of the term but rather a temporary localized shortage of soluble Ca during a period of great need. Ca may be present but the movement within the plant may be so slow that merristimatic tissues receive an inadequate supply for proper metabolic activities. Many authors reported that Ca availability, uptake and mobility is affected by the environmental conditions (4, 8, 9). Among the important environmental components affecting movement are moisture, light intensity, temperature and salt concentration in the medium.

Low or excessive moisture, in the soil will favor the incidence of tipburn (8). It is evident that over-watered plants will suffer from water stress which is induced by poor aeration. It may also cause root injury which will impair the uptake of nutrients. However, salt concentration is also related to soil moisture. When it is dry, salt concentration becomes higher which favors the occurrence of the disorder. It is reported (8) that growing tomatoes in a solution having an osmotic pressure above 1.70 atm would induce blossom end rot (BER) in as high as 80% of the fruits. The BER of tomato, however, is due to Ca shortage. Deficiency of Ca occurs during the period when the need by plants is at a peak or when an imbalance in the Ca/SSS (soil-soln-salt) ratio occurs in the soil in time of drought or when fertilizer such NH_4NO_3 is applied (3). The effects of other nutrients have no clear evidences; but these can all be related in some manner to their influence on uptake, translocation and metabolic activity of Ca in the plant.

Light intensity is another important factor due to its effect on the rate of photosynthesis and consequently on the growth of plants. Extended light during and high light intensity can increase tipburn incidence (8). Growth rate influences the occurrence of tipburn. Rapid growth stimulation may create a Ca demand that cannot be obtained from the Ca available in the soil solution.

Temperature is an equally important factor of tipburn incidence due probably to its effect on transpiration rate. An increase in temperature accompanied by higher light intensities is likely responsible for the faster growth rate and eventually accelerated rate of tipburn (11). Statistical analysis indicated a significant difference among means for insect damage for different frequencies of application (Table 8). However, the damage was very slight (less than 3 percent).

Conclusion

Foliar Ca application is not necessary if soluble Ca is present in the soil in high amounts and the conditions for the uptake and translocation of this element are adequate. The necessary conditions for sufficient mobility of this element are not exactly defined. In view of this, further studies should be done first before clear and exact conclusions can be drawn.

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Table 1. Properties of soil in AVRDC Field No. 31.

Field No.	pH	EC (m mho)	O.M (%)	T–N (%)	Available (ppm) P_2O	K_2O	CaO
31 (Top soil)	7.92	0.37	0.74	0.054	38	56	2200
31 (Sub soil)	8.07	0.25	0.72	0.051	39	38	2400

Table 2. Air temperature, relative humidity, solar intensity, evaporation, and precipitation in AVRDC (October-December, 1977).

	Air Temp Max	Air Temp Min	Soil Temp 10 cm	Relative humidity	Solar intensity	Evap	Pptn
	°C	°C	°C	%	Ca/cm²	mm	mm
Oct.	30.1	19.7	27.8	77.0	414.5	5.07	0.01
Nov.	25.9	15.5	24.0	78.4	307.8	3.89	0.91
Dec.	26.6	15.8	22.1	76.8	295.3	3.26	0.56
Mean	27.5	17.0	24.6	77.4	339.2	4.07	0.49

Table 3. Effect of frequency and rate of foliar Ca application on the yield, mean head weight, tipburn incidence and head rot incidence in Chinese cabbage.

Rate of $CaCl_2$	Frequency	Marketable head	Meanhead wt.	Tipburn incidence	Head rot incidence
(ppm)	(days)	(t/ha)	(gm)	(%)	(%)
0	10	40.2	1365	0	0
	15	38.7	1302	0	0
	20	45.6	1442	0	0
3000	10	42.2	1378	0	0
	15	42.6	1400	0	0
	20	40.3	1349	0	0
6000	10	43.1	1387	0	0
6000	10	43.1	1387	0	0
	15	42.4	1386	0	0
	20	42.8	1428	0	0
Mean		42.0	13.81	0	0
C.V. (%)		7.5	7.9	0	0
LSD .05 A		3.2^{ns}	109.8^{ns}	ns	ns
B		3.2^{ns}	109.8^{ns}	–	–
AB		2.6^{ns}	89.8^{ns}	–	–

ns = not significant.

Table 4. Effect of frequency and rate of foliar Ca application on soft rot infection and insect damage in Chinese cabbage.

Rate of $CaCl_2$	Frequency	Soft rot infection	Downy mildew rating+	Insect damage rating+
(ppm)	(days)	(%)	–	–
0	10	11.6	1	0.3
	15	10.0	1	0
	20	5.0	1	0.3
3000	10	8.3	1	0
	15	8.3	1	0
	20	10.0	1	0.6
6000	10	6.6	1	0.6
	15	8.3	1	0
	20	10.0	1	0.3
Mean		8.7	1	0.4
C.V. (%)		38.1	0	24.1
LSD .05	A	4.8ns	–	0.22ns
	B	4.8ns	–	0.22*
	AB	3.9ns	–	0.18ns

+Rating used: 0%, no infection or damage; 1-25%, light; 26-50%, moderate; 50% and above, heavy.

ns – non-significant.
* – significant at 5% level.

Table 5. Effect of frequency and rate of foliar Ca application on the yield of Chinese cabbage (ton/ha).

Frequency (days) / Rate of $CaCl_2$ (ppm)	10	15	20	Mean
0	40.2	38.7	45.6	41.5
300	42.2	42.6	40.3	41.7
600	43.1	42.4	42.8	42.7
Mean	41.8	41.2	42.9	41.9

Table 6. Effect of frequency and rate of foliar Ca application on mean head weight of Chinese cabbage (gm).

Frequency (days) / Rate of $CaCl_2$(ppm)	10	15	20	Mean
0	1365	1302	1442	1370
300	1378	1400	1349	1376
600	1387	1386	1428	1400
Mean	1377	1363	1406	1382

Table 7. Effect of frequency and rate of foliar Ca application on soft rot incidence in Chinese cabbage (%).

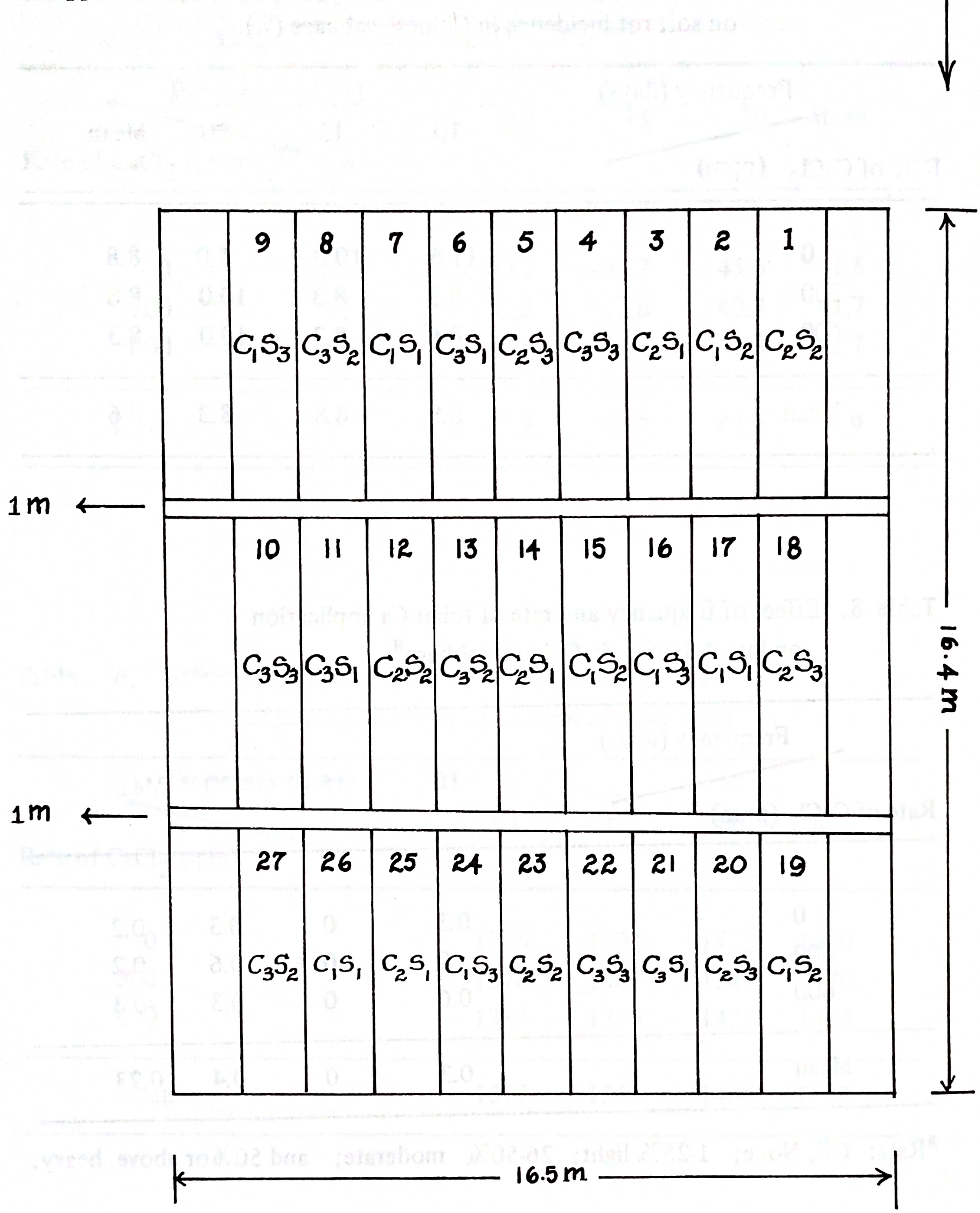
Rate of $CaCl_2$ (ppm) \ Frequency (days)	10	15	20	Mean
0	11.6	10.0	5.0	8.8
300	8.3	8.3	10.0	8.8
600	6.6	8.3	10.0	8.3
Mean	8.8	8.8	8.3	8.6

Table 8. Effect of frequency and rate of foliar Ca application on insect damage in Chinese cabbage[a].

Rate of $CaCl_2$ (ppm) \ Frequency (days)	10	15	20	Mean
0	0.3	0	0.3	0.2
300	0	0	0.6	0.2
600	0.6	0	0.3	0.3
Mean	0.3	0	0.4	0.23

[a]Rate: 0%, None; 1-25%. light; 26-50%, moderate; and 50% or above, heavy.

Appendix Figure: Field Layout



Plot size = 1.5 m x 4.8 = 7.2 m^2

No. of rows per plot = 2

Distance between furrows = 1.5 m

No. of plants per plot = 24

Appendix Figure No. 2. Time Table of Activities

DAYS	DATE	ACTIVITIES
	Oct 12	Land preparation, basal fertilization, compost incorporation, bed formation and herbicide application
0	Oct 13	Direct seeding and irrigation
4	Oct 17	Irrigation
8	Oct 21	Thinning, Insecticide and Fungicide sprayings
10	Oct 23	Apply starter solution, First calcium spraying (S_1, S_2, S_3)
11	Oct 24	Hand weeding and mulching rice straw
15	Oct 28	Insecticide and Fungicide sprayings
20	Nov 2	Calcium spraying (S_1), First side dressing and Irrigation
22	Nov 4	Insecticide and Fungicide sprayings
25	Nov 7	Calcium spraying (S_2), Hand weeding
30	Nov 12	Calcium spraying (S_1, S_3), Second side dressing and irrigation
32	Nov 14	Insecticide and Fungicide sprayings
40	Nov 22	Calcium sprayings (S_1, S_2), Hand weeding
44	Nov 26	Third side dressing, Irrigation, Insecticide and Fungicide sprayings
50	Dec 2	Calcium spraying (S_1, S_3)
55	Dec 7	Calcium spraying (S_2), Insecticide and Fungicide spraying
58	Dec 10	Fourth side dressing, Irrigation
60	Dec 12	Calcium spraying (S_1)
65	Dec 17	Irrigation
70	Dec 22	Calcium spraying (S_1, S_2, S_3)
75	Dec 27	Irrigation, Insect pests and disease rating "sampling"
90	Jan 11	Data collection, harvesting