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The Influence of Antitranspirant and Calcium Sprays on Calcium Distribution and Tipburn in Cabbage *(Brassica oleracea var. capitata)* and Lettuce *(Lactuca sativa L.)*

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ABSTRACT

Tipburn is a widespread physiological disorder of cabbage and lettuce, caused by calcium deficiency. Symptoms of tipburn are necrosis on margins of outer and inner head leaves in lettuce, whereas in cabbage it is only on margins of inner leaves. Tipburn on outer leaves may develop early, but symptoms remain the same until harvest. Tipburn is more serious when it occurs on the inner leaves as heads approach maturity.

In search of tipburn control, foliar calcium ($Ca(NO_3)_2$ and $CaCl_2$) sprays were applied to the entire leaves to increase calcium content, and foliar Folicote antitranspirant spray was applied to outer frame leaves to reduce transpiration, stimulate root pressure flow and increase movement of calcium to inner leaves.

Foliar sprays of antitranspirant, calcium. and combined sprays of antitranspirant and calcium resulted in a degree of tipburn control and in an increase in calcium content of inner leaves, but failed to adequately control tipburn, Most effective was a combined spray of antitranspirant and $CaCl_2$, next were $CaCl_2$, combined spray of antitranspirant and $Ca(NO_3)$, then antitranspirant alone and least effective was $Ca(NO_3)_2$.

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Foliar sprays of antitranspirant, calcium, and combined sprays of antitranspirant and calcium resulted in slightly higher head temperatures in cabbage and lettuce, and a tendency to increase uptake of some mineral elements such as K, P, Mg, and B.

INTRODUCTION

Tipburn is a widespread physiological disorder of cabbage and lettuce, which occurs in nearly all of the producing areas in the United States, in both field and greenhouse. Tipburn is also a serious disease in tropical and subtropical areas.

Tipburn is of nonparasitic origin, not caused by a virus, bacterium, fungus or insect (6, 40, 46, 65, 69); demonstrated by the fact that the disease can not be transmitted in the tissues (59, 65).

Many factors affect the development of the disorder, these include humidity (8, 29, 37, 43, 59, 60, 61, 69, 70), temperature (1, 15, 16, 37, 59, 60, 71), intensity and duration of light (12, 16, 51, 53, 58, 59, 60, 62), transpiration rate (1, 5, 13, 14, 21, 26, 27, 29, 38, 45, 55, 57, 64, 66, 70), soil moisture (1, 2, 4, 7, 10, 12, 29, 33, 40, 64, 65, 68, 69), mineral imbalance (3, 29, 31, 36, 38, 45, 50, 53, 54, 56, 58, 59), excess nitrogen (3, 24, 39, 42, 48, 52, 53, 65), and plant growth (14, 16, 18, 38, 41, 43, 47, 58).

Cabbage and lettuce tipburn may be considered typical of growing point disorders where calcium deficiency occurs as the leaf emerges from the growing point. Tipburn may also occur later when the head is developing (36). Tipburn is more serious when it occurs on internal leaves as the head approaches maturity.

In one series of experiments, initial symptoms of tipburn were small, dark-brown spots along the margins of the outer head leaves in lettuce (but not in cabbage). These spots later coalesced, and the entire margin became brown and necrotic, then it occurred on the internal leaves of the head as maturity approached (41).

Internally, the dark-brown necrotic areas have an unappetizing appearance. These limit salability of heads and cause a great problem for both farmer and consumer, as symptoms can not be seen without cutting and tearing the heads apart. The internal necrotic areas are ideal sites for secondary infections by bacterial and/or fungal rotting microorganisms which often cause a watery break-down of the tissue commonly known as slime (59, 69). Usually only a few leaves of the head are affected with tipburn, but this can cause the entire head to become very quickly unsalable during the period of maturity. Entire fields may be ruined by the disease during a few days of warm weather.

There is no good control of this disorder in the field; some researchers, however, have significantly increased our understanding of the disease. Tibbitts et al. (61, 63) and Olson (43) have found a relationship between laticifers and lettuce tipburn. They identify the cause of necrotic symptoms along leaf margins as a rupture of laticifers and release of latex into surrounding parenchyma cells resulting in cell collapse and necrosis. Ashkar and Ries (3) reported convincing experimental evidence that calcium metabolism of the plant under conditions of limited calcium availability, as affected by some environmental conditions, may be influential in producing tipburn.

Agricultural scientists studying the problems of calcium on tipburn of cabbage and lettuce in greenhouse, consider calcium deficiency in plant tissues as the most important factor (3, 28, 29, 34, 36, 38, 45, 50, 53, 54, 56, 58, 59). Some obtained complete or partial control by foliar calcium sprays in greenhouse or growth chamber (14, 29, 58), but none obtained control of tipburn on cabbage and lettuce in the field (25, 65), probably because it is more difficult to control field environmental conditions.

The purpose of this study is to use foliar calcium sprays in order to increase calcium content, and foliar antitranspirant sprays on frame leaves of cabbage and lettuce plants to reduce uptake in these treated leaves, increase root pressure flow and shift calcium from outer to inner leaves. The use of antitranspirant in this manner has not been reported in the literature.

MATERIALS AND METHODS

Experiments were conducted with Greenboy cabbage (*Brassica oleracea* var. capitata) and Pennlake lettuce (*Lactuca sativa* L.), chosen for their susceptibility to tipburn.

Plots were direct seeded. Cabbage was sown on May 28, and lettuce on June 1, 1981 at the vegetable research farm, Oregon State University on sandy loam soil.

Plant spacing was 25 cm in row, 90 cm between rows for lettuce, and 30 cm and 90 cm for cabbage. Plots were 7 m long with 2 rows each. Lettuce plots had 24 plants, and cabbage 20. Thinning was done 30 days after seeding.

Plots were irrigated by overhead sprinkler as needed. Irrigation was applied every 5-7 days dependant on weather and soil moisture conditions. Fertilizer application consisted of 45 kg/ha nitrogen, 70 kg/ha phosphorus and 36 kg/ha potassium for both cabbage and lettuce. Weeds were controlled by hand. Sevin was used for insect control.

Treatments included Folicote antitranspirant at 1%, 3%, and 5% with 0.05 molar calcium nitrate or calcium chloride foliar sprays. Folicote is a wax emulsion, a product of Crystal Soap and Chemical Co. The 12 foliar spray experimental treatments were as follows:

1. Control (water spray).
2. Calcium nitrate ($Ca(NO_3)_2$) 0.05 molar.
3. Calcium chloride ($CaCl_2$) 0.05 molar.
4. Antitranspirant 1%.
5. Antitranspirant 1% + $Ca(NO_3)_2$ 0.05 molar.
6. Antitranspirant 1% + $CaCl_2$ 0.05 molar.
7. Antitranspirant 3%.
8. Antitranspirant 3% + $Ca(NO_3)_2$ 0.05 molar.
9. Antitranspirant 3% + $CaCl_2$ 0.05 molar.
10. Antitranspirant 5%.
11. Antitranspirant 5% + $Ca(NO_3)_2$ 0.05 molar.
12. Antitranspirant 5% + $CaCl_2$ 0.05 molar.

All 12 treatments were replicated 4 times and arranged in a randomized block design. Cabbage plots were treated with two applications of antitranspirant and eight applications of calcium nitrate and calcium chloride. The first antitranspirant and calcium sprays were applied 50 days after seeding. A second antitranspirant application was made one month later. Calcium sprays were applied one week apart. One application of antitranspirant and four applications of calcium were applied to lettuce. Antitranspirant and calaium sprays were applied 45 days after seeding. Subsequent calcium sprays were one week apart. Foliar antitranspirant and calcium sprays in cabbage were twice as many as those of lettuce, since the cabbage growing season was 40 days longer than lettuce.

Antitranspirant was sprayed on both sides of frame leaves. Calcium was applied to the entire plant.

Calcium sprays were intended to increase calcium content while antitranspirant sprays were applied to reduce or slow transpiration from frame leaves in order to stimulate development of root pressure flow for movement of calcium to inner leaves.

Head temperature measurements were made on August 3 in lettuce, two weeks after spraying antitranspirant, and September 4 in cabbage, two weeks after the second antitranspirant spray with a Telatemp Infrared Thermometer, model AG-42. Five uniform size heads in each plot were chosen to measure temperature. Temperatures were measured at near solar noon (12:00-13:30 p.m.), data for cabbage and lettuce.

Lettuce plots were harvested on August 11 to 12 and cabbage on September 21 to 22.

Tipburn evaluation was made by cutting open all heads and rating severity of tipburn on a scale from 0 (no tipburn), 1 (slight) to 5 (very serious).

Two leaf samples of frame, cap, and inner leaves from eight heads in each plot were analyzed for calcium and other mineral content. Plant tissues from treatments of 1, 2, 3, 10, 11, and 12 were used for tissue analysis. Tissue was washed first in water, Then in a solution of 10 g of EDTA, Disodium salt in 20 ℓ of distilled water, and the last time in distilled water to tie up and remove any calcium residue from the foliar sprays which might have confounded tissue analysis for calcium. The clean tissue was placed in a tunnel drier for initial drying at 70°C for 48 hours. Tissue was ground in a Wiley mill and further dried for thirty minutes to remove moisture. One gram samples of each treatment were used for analysis. These were ashed in a Muffle (Thermolyne) for 6 hours, then treated with 5 ml of an internal standard solution consisting of 0.1% Co and 0.5% Li. A direct-reading Spark Emission Spectrometer was used for the mineral analysis.

Data were analyzed by analysis of variance and the means compared with Duncan's Multiple Range Test or T test whenever F values were significant.

RESULTS AND DISCUSSION

Although differences were not significant at the 5% confidence level (Fig. 1), foliar sprays of antitranspirant, calcium, and combined sprays of antitranspirant and calcium reduced cabbage and lettuce tipburn when compared with control. Analysis of treated and untreated plants showed that certain treatments markedly increased the calcium content of cap and tipburn susceptible inner leaves (Tables 2 and 3). Calcium nutrition generally is recognized to influence cabbage and lettuce tipburn development. Calcium transport to inner leaves of cabbage and lettuce plants was enhanced when transpiration was reduced from the frame leaves by antitranspirant spray. Calcium content was increased in inner leaves by calcium spray. Both antitranspirant and calcium sprays reduced tipburn severity.

TIPBURN SEVERITY INDEX

In lettuce, plots treated with $ca(NO_3)_2$ resulted in a slightly higher tipburn severity index than $CaCL_2$ (Fig. 1). When $Ca(NO_3)_2$ was applied to increase calcium content and to reduce tipburn in cabbage and lettuce, it also added extra nitrogen. This may have increased plant growth to a degree that nullified the advantage of calcium addition, because tipburn is easily induced by high NO_3 nutrition when applied to foliage (3, 48).

In different antitranspirant rate sprays on lettuce, no clear trends were noted.

Combined sprays of 1%, 3%, and 5% antitranspirants + $CaCL_2$ gave slightly less tipburn than combined sprays of 1%, 3%, and 5% antitranspirants + $Ca(NO_3)$ in cabbage and lettuce. This was probably due to extra nitrogen applied with the $Ca(NO_3)_2$ which may have aggravated tipburn. The slight differences noted between combined sprays of antitranspirant rates and calcium may be due to the compensating benefits of the antitranspirant.

Combined sprays of antitranspirant + $CaCl_2$ resulted in the least tipburn in cabbage and lettuce (Fig. 1), antitranspirant and $CaCl_2$ were partly effective in moving calcium to inner leaves (13, 17, 21, 28, 29, 56, 58).

In cabbage, small size heads (<20 cm in diameter) were less susceptible

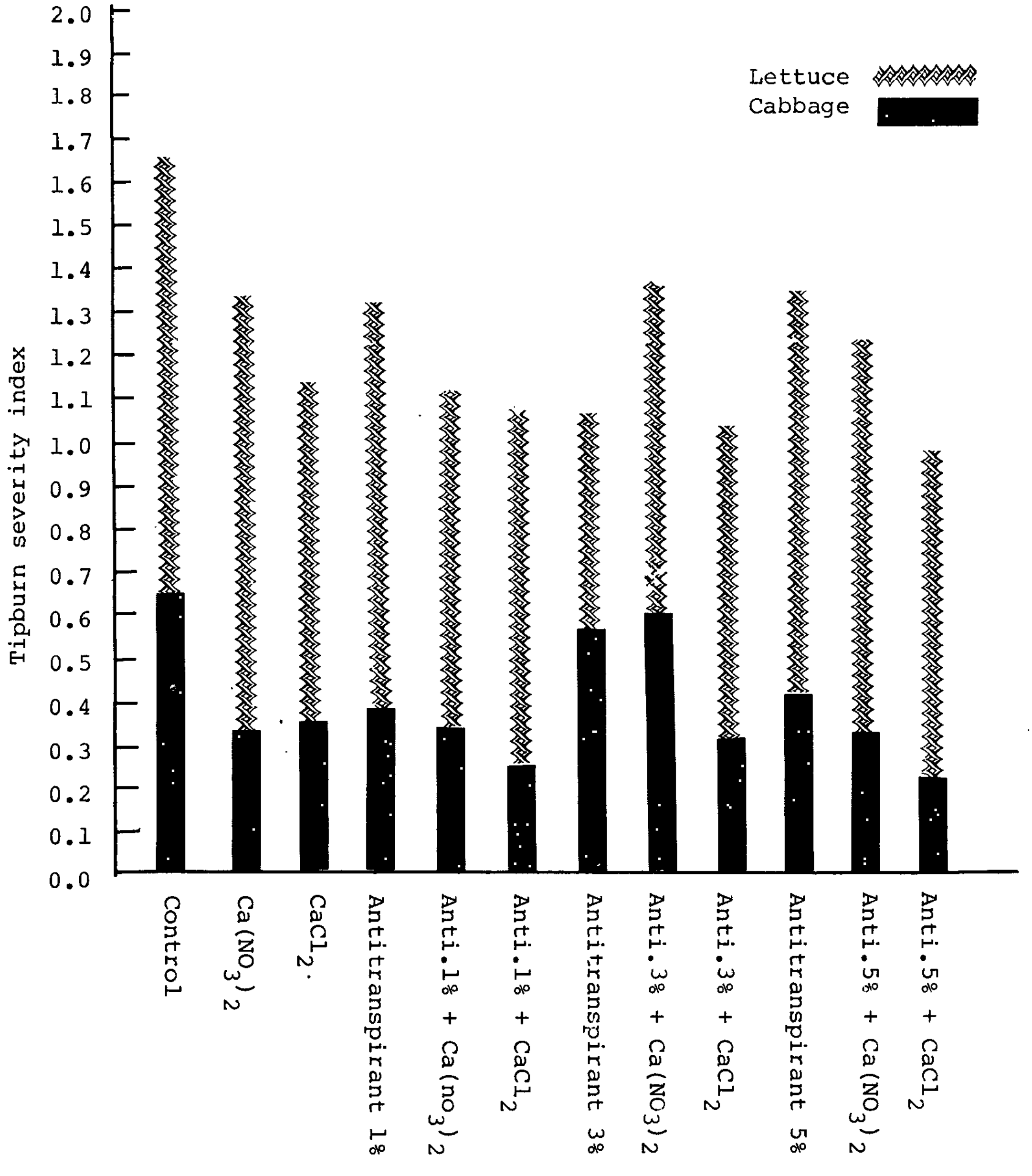

Fig 1. Effect of antitranspirant and calcium foliar sprays on tipburn severity index[z] in lettuce and cabbage.

z. Severity index is mean rating of heads with tipburn symptoms on scale from 0 (none), 1 (slight) to 5 (very serious). No significant differences at 5% level in lettuce and cabbage.

to tipburn (Table 1). Small size heads would be due to slowed growth which would result in increased calcium content (21).

The effects of antitranspirant and calcium sprays expressed as percent tipburn were similar to tipburn severity index in both cabbage and lettuce. Yet percent incidence data may be misleading, because infected heads may have very little tipburn, therefore severity index data was used throughout this report.

CALCIUM DISTRIBUTION

Foliar calcium sprays on entire cabbage and lettuce plants increased calcium content of cap and inner leaves in this study (Tables 2 and 3). Similar results were reported by Kruger (28), Kuo et al. (29), and Thibodeau et al. (58) in greenhouse and growth chamber studies.

Antitranspirant spray on frame leaves of cabbage and lettuce tended to reduce plant transpiration thereby resulting in reduced accumulation of calcium in frame leaves, and increased root pressure flow and calcium movement to inner leaves, reducing tipburn. Table 2 shows that there are no significant differences between treatments in calcium levels of frame leaves of cabbage. This may be because frame leaves had already absorbed enough calcium when sprayed with antitranspirant by 50 days after planting.

Combined sprays of antitranspirant and calcium resulted in increased calcium content of cap and inner leaves in cabbage and lettuce, but didn't move more calcium than calcium spray alone and antitranspirant spray alone (Tables 2 and 3). These results indicated that there may not be an interaction existing between antitranspirant and calcium.

Foliar sprays of calcium, antitranspirant, and combined sprays of antitranspirant and calcium increased calcium content of cap leaves and inner leaves in cabbage and lettuce (Tables 2 and 3), but failed to effectively prevent tipburn in this study (Fig. 1). The calcium content of inner leaves is probably still not sufficient to prevent tipburn development. Perhaps adding surfacant to antitranspirant and calcium solution could be important, since it was difficult to get good coverage of cabbage and lettuce leaves due to waxes existing in cabbage and lettuce, particularly in cabbage. Furthermore, maybe frame leaves should have been sprayed much sooner than the 50^{th} day so that they would not accumulate calcium. Wiebe et al. (70) reported that in cabbage, tipburn occurred on inner leaves with calcium content of 0.3%; more resistant cap had 0.65% and outer leaves had from 3 to 7%. Misaghi and Grogan (38) showed that the inner susceptible leaves contained 0.8%. Since foliar sprays of calcium, antitranspirant, and combined sprays of antitranspirant and calcium resulted in an average 0.3% calcium level in inner leaves of cabbage (Table 2), and 0.7% in lettuce (Table 3), better control of tipburn may have been realized if a less susceptible variety of cabbage and lettuce was used.

Palzkell et al. (44, 45), and Kuo et al. (29) found that root pressure flow can translocate calcium to inner leaves of cabbage for prevention of cabbage tipburn by coverage of cabbage leaves to stop transpiration, and Palzkill et al. suggested that application of chemicals to reduce stomatal opening may be effective, but did not mention what kinds of chemicals.

Table 4 shows that frame and cap leaves in cabbage, and cap leaves in lettuce have higher calcium content than inner leaves. These leaves did not develop tipburn. The results indicated that tipburn development was related to calcium content.

Table 1. Effect of antitranspirant and calcium foliar sprays on tipburn severity index in different size heads[z] in cabbage.

Treatments	Large	Small
Control	1.21	0.09
$Ca(NO_3)_2$	0.71	0.00
$CaCl_2$	0.82	0.00
Antitranspirant 1%	0.77	0.00
Anti. 1% + $Ca(NO_3)_2$	0.75	0.00
Anti. 1% + $CaCl_2$	0.49	0.00
Antitranspirant 3%	1.07	0.04
Anti. 3% + $Ca(NO_3)_2$	0.91	0.02
Anti. 3% + $CaCl_2$	0.65	0.03
Antitranspirant 5%	0.88	0.04
Anti. 5% + $Ca(NO_3)_2$	0.57	0.00
Anti. 5% + $CaCl_2$	0.42	0.00

Z. Large size of head> 20 cm in diameter. Small size of head< 20 cm in diameter.

Table 2. Effect of antitranspirant and calcium foliar sprays on calcium content in cabbage.

Treatments	Calcium content[Z] (% of dry weight)		
	Frame leaves[X]	Cap leaves[Y]	Inner leaves[Y]
Control	2.22	0.66 a	0.27 a
$Ca(NO_3)_2$	2.22	0.76 b	0.31 b
$CaCl_2$	2.26	0.82 b	0.30 b
Antitranspirant 5%	2.21	0.76 b	0.29 ab
Anti. 5% + $Ca(NO_3)_2$	2.24	0.74 ab	0.30 b
Anti. 5% + $CaCl_2$	2.26	0.75 ab	0.30 b

Z. Means of 4 replications.

X. No significant differences at 5% level.

Y. Mean separation within column by Duncan's multiple range test at 5% level. Means connected by the same letter are not significantly different.

Table 3. Effect of antitranspirant and calcium foliar sprays on calcium content in lettuce.

Treatments	Calcium content[Z] (% of dry weight)	
	Cap leaves[X]	Inner leaves[Y]
Control	1.00	0.58 a
$Ca(NO_3)_2$	1.17	0.72 b
$CaCl_2$	1.27	0.70 b
Antitranspirant 5%	1.23	0.67 ab
Anti. 5% + $Ca(NO_3)_2$	1.24	0.71 b
Anti. 5% + $CaCl_2$	1.27	0.69 b

Z. Means of 4 replications.

X. No significant difference at 5% level.

Y. Mean separation within column by Duncan's multiple range test at 5% level. Means connected by the same letter are not significantly different.

Table 4. Overall calcium content of frame, cap, and inner leaves in cabbage and lettuce.

Leaves	Calcium content (% of dry weight)	
	Cabbage[X]	Lettuce[Y]
Outer leaves	2.22 a	——
Cap leaves	0.75 b	1.20
Inner leaves	0.30 c	0.67

X. Mean separation within column by Duncan's multiple range test at 5% level. Means connected by the same letter are not significantly different.

Y. Significant difference at 1% level by t test.

HEAD TEMPERATURE

The Folicote antitranspirant sprays in this study appeared to have increased head temperature by 0.5-1.0°C in cabbage, and 1.0-2.0°C in lettuce compared with control (Table 5). These differences appear small. Film-forming antitranspirants tend to increase leaf temperature by curtailing transpiration rates. Coverage of frame leaves only was intentional so as not to aggravate tipburn by adversely stopping plant cooling. Small differences in temperature would be expected from partial plant coverage.

Although air temperature was lower when the cabbage temperature was taken, solar radiation was higher and may have accounted for part of this difference.

Head temperature affects tipburn development. Although antitranspirant sprays increased head temperatures very little in one study (20), and apparently not significantly in this experiment, the failure to control tipburn by antitranspirant sprays may be due in part to increasing temperature as well as a failure to move enough calcium to inner leaves.

DISTRIBUTION OF OTHER MINERAL ELEMENTS

Although no significant differences were noted at the 5% level in distribution of other mineral elements, it was found that boron content in healthy tissue of outer leaves was about 20 ppm lower than that in diseased tissue of inner leaves of cabbage, therefore, probably boron was not likely to be involved in tipburn in this study, confirming most other reports, although some authors reported the possible involvement of boron in cabbabe and lettuce tipburn development (9, 19, 29).

No significant differences were found in other element content such as K, P, Mg, Fe, Cu, and Zn among treatments in both cabbage and lettuce, but there was a tendency to affect K, P, Fe, and Zn uptake in cabbage inner leaves, and affect K, Mg, P, Mn, B, and Zn uptake in lettuce inner leaves by antitranspirant sprays, calcium sprays, and combined sprays of antitranspirant and calcium.

The results indicated that P, K, Mg, Cu, Fe, B, and Zn may have no effect on tipburn and calcium content in cabbage and lettuce. Similar results were reported by Sonneveld and Ende (56) they studied the effects of various salts on tipburn of lettuce and found that salts such as NaCl, $MgCl_2$, $NaHNO_3$, Na_2SO_4, KCl, and $NaNO_3$ did not control tipburn; only $CaCl_2$ prevented the disorder almost completely. Nieuwhof (41) found that different foliar calcium sprays on lettuce did not increase content of other mineral elements.

Table 5. Head temperature of cabbage and lettuce.

Treatments	°C	
	Cabbage[X]	Lettuce[Y]
Control	32.74	28.34
$Ca(NO_3)_2$	32.57	29.34
$CaCl_2$	33.05	29.06
Antitranspirant 1%	33.26	30.03
Anti. 1% + $Ca(NO_3)_2$	32.83	29.27
Anti. 1% + $CaCl_2$	33.05	30.44
Antitranspirant 3%	33.66	30.12
Anti. 3% + $Ca(NO_3)_2$	33.18	30.12
Anti. 3% + $CaCl_2$	33.08	30.28
Antitranspirant 5%	33.56	30.71
Anti. 5% + $Ca(NO_3)_2$	32.88	30.51
Anti. 5% + $CaCl_2$	33.43	30.93

X. No significant differences at 5% level. Air temperature 22°C. Solar radiation 1900$\mu\varepsilon m^{-2}$ sec^{-1}.

Y. No significant differences at 5% level. Air temperature 24.79°C. Solar radiation 1150$\mu\varepsilon m^{-2}$ sec^{-1}.

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抗蒸發劑及鈣對甘藍及結球萵苣之頂燒病及鈣分佈之影響

摘　　　要

陳 榮 五[1]

頂燒病是甘藍及結球萵苣很普徧的因缺鈣而引起的生理病，其病徵在結球萵苣是球內部葉片及外部葉片之葉緣焦化，而在甘藍則祇發生於內部葉片。頂燒病發生於外部葉片很早但其病症到收穫時一直保持一樣，對植株本身無傷害作用。但發生於內葉當接近收穫時則非常嚴重而失去商品價值。

葉面施用抗蒸發劑及鈣可減少頂燒病之發生及增加球內部葉片之鈣含量。但不能完全控制頂燒病之發生。最有效的是同時使用抗蒸發劑及 $CaCl_2$，其次爲施用 $CaCl_2$，然後爲同時施用抗蒸發劑及 $Ca(NO_3)_2$ 及單用抗蒸發劑，最差的是單用 $Ca(NO_3)_2$ 。

葉面施用抗蒸發劑因仰制蒸散作用之故，有稍提高球溫度之現象，並有增加一些元素如K、P、Mg 及B之含量之趨向。

全葉面施用抗蒸發劑在外葉片可仰制葉片之蒸散作用，刺激根壓而增加鈣之移動到內部葉片。

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