Effect of Temperature on Tipburn Development in Head Lettuce

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ABSTRACT

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Tipburn symptoms developed on the central leaves of mature detached field-grown heads of lettuce exposed in growth chambers to 24 to 33 C for 4 to 7 days. Tipburn severity also was enhanced by enclosing mature intact plants in the field with polyethylene-covered frames that raised head temperature about 6 C above the ambient temperature outside the enclosures. Percentage of tipburned plants and disease severity increased directly with increase in time of exposure to tipburn-inducing temperatures. At all temperatures tested, about twice as much time was required to induce tipburn in 50% of the heads subjected to alternating high and low temperatures as compared with constant temperatues. Differences in vapor pressure deficits during temperature treatment did not affect tipburn development in harvested heads. Internal temperatures of mature heads in the field during sunny days usually was about 6 C higher than ambient, which may be the reason why tipburn may occur at times when ambient temperatures do not exceed 24 C, the minimum temperature for tipburn induction under laboratory conditions.

Additional key words: tolerance, resistance.

Tipburn, a nonparasitic disease of lettuce, is sporadic in occurrence but usually is more prevalent in nearly mature lettuce during warm summer months. The disease is characterized by a necrotic breakdown of the marginal leaf tissues within the heads and a darkening of veins in affected areas (Fig. 1). The loose outer leaves usually are not affected; thus symptoms are evident only after removal of outer leaves. The disease varies in incidence, and most plantings are not affected severely, because the place and time of commercial planting usually is chosen to avoid hot weather.

Several environmental factors have been associated with tipburn development. Some reports indicate that high ambient relative humidity (RH) favors the disease (6, 16, 18), whereas others (7, 21) have reported that low ambient humidity is more conducive to it. Other factors that have been associated with tipburn development include high light intensity (2, 18, 20); high (4, 5, 14, 18), low (1, 21) and variable (7) soil moisture; high soil fertility and salinity (2, 3, 9, 17, 21); high ambient CO_2 concentration (16); increased transpiration (10, 22); and increased growth rates (8). Newhall (14) suggested that high temperature in the field is an important factor in tipburn development, and Thompson (18) reported that increase in ambient temperature in humid chambers increased tipburn severity. Andersen (1) reported a close correlation between tipburn severity and the difference between maximum air and soil temperatures. Tibbitts and Bottenberg (19) reported tipburn development in Bibb lettuce plants in growth chambers within 16 hr after plants were transferred from 21 to 29 C, but tipburn did not develop in control plants kept at 21 C. Cox et al (8) reported a direct correlation between temperature and tipburn injury of lettuce grown under constant illumination. Since reduction in illumination at a constant temperature resulted in delay in tipburn development, however, they suggested that temperature was not the sole inducer.

Since the reported role of temperature on tipburn development has not been consistent, this study was undertaken to determine quantitatively the influence of constant and alternating temperatures on incidence and severity of tipburn on excised heads in the laboratory and on intact plants in the field. Also, several cultivars with relative differences in tipburn tolerance were compared to determine severity of tipburn after exposure to tipburn-inducing temperatures.

MATERIALS AND METHODS

Induction of tipburn.—Heads of lettuce (*Lactuca sativa* var. *capitata* L.) obtained by random selection from fields in the Salinas Valley of California at the time of commercial harvest were subjected to constant temperatures (21, 24, 27, and 30 C), 12 hr of light (18,000 lx) daily, and 70% RH in environmental growth chambers. Tipburn incidence and severity were determined after 1, 2, 3, 4, 5, 7, and 10 days of exposure to the different temperatures. Tipburn severity was estimated on a scale from 0.5 to 5.0 to indicate slight to severe symptoms in damaged heads.

Effect of temperature and RH.—Mature detached Calmar lettuce heads were subjected to constant temperatures—0, 5, 10, 15, 21, 24, 27, 30, 33, and 36 C—with a 12-hr photoperiod in growth chambers. Relative humidity at all of the temperatures ranged from 43 to 52%. Values of vapor pressure deficit (VPD), which

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increased with increase in temperature under constant RH, were 14, 18, 20, 23, 27, and 32 mb for temperatures of 21, 24, 27, 30, 33, and 36 C, respectively, at 47% RH. To separate the effect of VPD from that of temperature, detached mature heads also were subjected to constant elevated temperatures (22, 27, 30, and 35 C) with a constant VPD of about 13 mb. This was accomplished by adjusting RH to 50% at 22 C, to 63% at 27 C, to 69% at 30 C, and to 76% at 35 C. Detached heads also were exposed to alternating temperature (12 hr of light daily at 22, 24, 27, 29, 32, or 35 C and 47 ± 4% RH and 12 hr at 21 C and 70% RH during the dark period). Temperature and RH were recorded continuously with a hygrothermograph and RH also was monitored daily with a wet-bulb psychrometer (Fisher Scientific, Pittsburgh, PA 15219). Tipburn severity, percentage of tipburned plants, and exposure period for induction of tipburn in 50% of the plants were determined during a 12-day period. This test was repeated four times, with 11 to 13 heads in each temperature treatment.

Effect of plant maturity.—Fifty mature detached Calmar lettuce heads collected randomly from a field were divided into three maturity categories based on head firmness—soft, medium, and hard. Plants were exposed in growth chambers to a constant 30 C and 47 ± 4% RH, with 12 hr of light daily, and rated for tipburn severity after 3 and 5 days. This test was repeated four times.

Relative responses of different lettuce cultivars to elevated temperature.—Cultivar Calmar, which is tolerant, and cultivar Calicel, which is more susceptible to tipburn, were grown in adjacent rows in a field plot in the Salinas Valley of California during April 1976. Randomly selected mature heads of the two cultivars were subjected in growth chambers to 30 C and 47 ± 4% RH, with 12 hr of light daily, and were rated for tipburn incidence and severity after 3 and 5 days. This test was repeated three times, with 15 heads of each cultivar.

Tipburn induction in the field.—To determine if tipburn severity and incidence could be increased in intact field-grown plants by increase of head temperature, frames (1 × 1.2 × 3.3 m) covered with polyethylene sheeting were placed for 6 to 7 days over 20–24 lettuce plants 1, 2, and 3 wk prior to harvest. Temperatures and RH inside and outside the frames were monitored with hygrothermographs during the experiment. This experiment was repeated five times in fields near Salinas and Brentwood, CA.

In another test to determine the relative response of lettuce cultivars to elevated temperatures, four cultivars of head lettuce (Calmar, Calicel, Cal K60, and Salinas) with different levels of field tolerance and grown in adjacent rows were enclosed under polyethylene-covered frames (2 × 2.4 × 4 m) for 6 days at 12 to 14 days before harvest. Thirteen to 15 plants of each cultivar were under each frame. At harvest, comparable plants inside and outside the frames were rated for tipburn incidence and severity.

Relationship between ambient temperature and head temperature.—During July and August of 1975, ambient and head temperatures at 0.6-, 1.25-, 2.5-, 5.0-, and 8.7-cm depths from the top of 20 to 25 heads were measured with a thermocouple potentiometer at 1-hr intervals on two different days from 0800 to 1800 in a field in the Salinas Valley of California 6 and 7 days before harvest. In another experiment, comparable data were obtained at 2-hr intervals for 24 hr.

RESULTS

Induction of tipburn.—Tipburn symptoms developed on the margins of the central leaves of mature detached field-grown heads exposed to 24 to 33 C for 4 to 6 days. Mild tipburn symptoms also developed, albeit inconsistently, on the middle leaves (situated between innermost [central] and outer portions of heads), but no symptoms developed on the three to five outermost leaves. Symptoms on the leaves of the mature detached heads appeared to be identical with naturally induced field symptoms (Fig. 1).

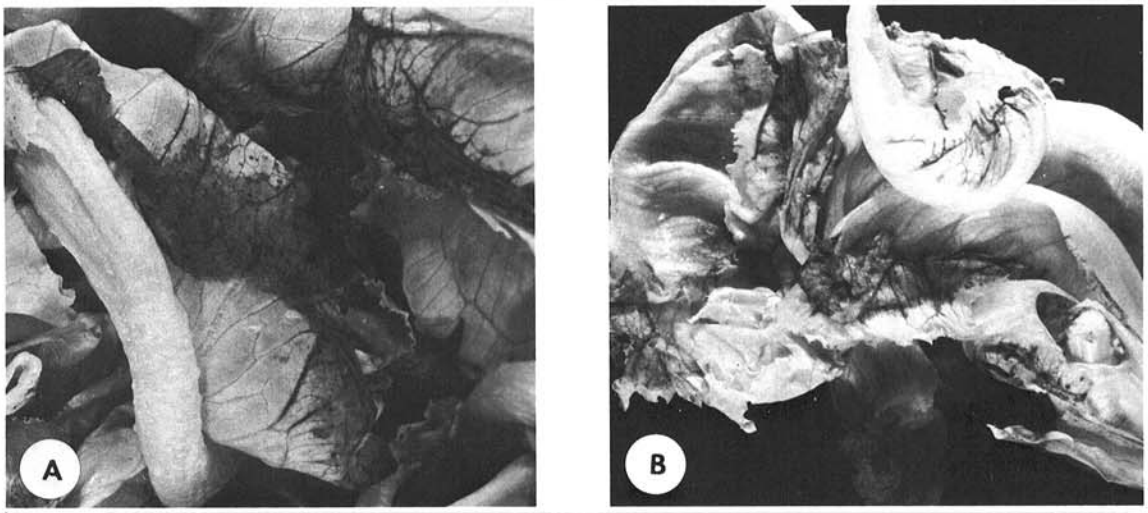

Fig. 1-(A, B). Tipburn symptoms on innermost leaves of mature heads of Calmar lettuce **A)** from field and **B)** induced in laboratory by subjecting detached heads for 5 days to constant 30 C and 47 ± 4% relative humidity (RH) with 12 hr of cool white fluorescent light daily.

Effect of temperature on tipburn development.—Temperature and tipburn development were closely correlated—within a given time of exposure, the higher the temperature, the greater the severity index and percentage of tipburned plants (Fig. 2). No tipburn developed in heads kept below 24 C, even after 10 days of exposure. Both tipburn severity and percentage of tipburned plants increased in direct proportion with increase in time of exposure to 30 C.

Tipburn incidence and severity were not significantly different in mature heads subjected to high temperatures whether the VPD was kept constant at 13 mb or varied from 13 to 35 mb. This indicates that tipburn development and severity is due mainly to increase in temperature rather than to changes in VPD. Within a given time period, tipburn was more severe in detached mature heads subjected to elevated constant temperatures than in comparable heads subjected to alternating high and low temperatures. When the differences between daily high and low temperatures were three or more degrees Centigrade, about twice as much time was required to induce tipburn in 50% of heads subjected to alternating high and low temperatures than in treatments subjected to constant temperatures (Fig. 3).

Depending on the difference between head temperature at the initiation of an experiment and temperature of growth chambers, 2–7 hr were required for head and ambient temperatures to equilibrate. For example, the number of hours required for temperatures of lettuce heads to change from 16 to 31 C or from 31 to 16 C were 5, 6, and 7 at 2.5, 5.0, and 7.5 cm depths within the heads, respectively. Temperature increased or decreased slightly faster in loose heads than in firm heads.

Effect of light and relative humidity.—The severity index and percentage of tipburn in heads subjected to 30 C and 12 hr of light daily for 5 days was greater than for heads kept at 30 C in the dark. The difference, however was not statistically significant. Tipburn incidence and severity also was increased slightly in direct proportion with increases in RH (Table 1), but only the difference in severity index between the lowest RH (33%) and the highest (98%) was significant ($P = 0.01$).

Effect of plant maturity on tipburn development.—Tipburn development in moderately firm heads was more severe than in firm or in soft heads. The respective average severity indexes of moderately firm, soft, and firm heads were 0.6, 0.4, and 0.2 after 3 days and 2.7, 2.0, and 1.5 after 5 days at 30 C. Each figure represents an average tipburn severity index of 51—55 heads in four replications. All differences were significant ($P = 0.01$).

Relative responses of different lettuce cultivars.—The tipburn responses of mature detached heads of cultivars

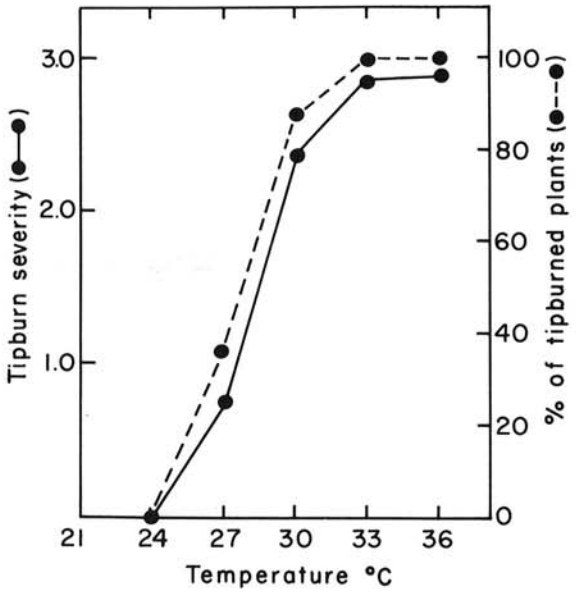

Fig. 2. Average tipburn severity index and percent of tipburned plants of mature detached Calmar lettuce heads subjected for 5 days to different constant temperatures and 47 ± 4% relative humidity with 12 hr of cool white fluorescent light daily. Severity index is mean rating of heads with tipburn symptoms on scale from 0.5 (very slight) to 5.0 (severe). Each point represents average rating of 43–46 heads in four repetitions. Not included are data for comparable heads exposed to 0, 5, 10, and 15 C that did not develop any tipburn.

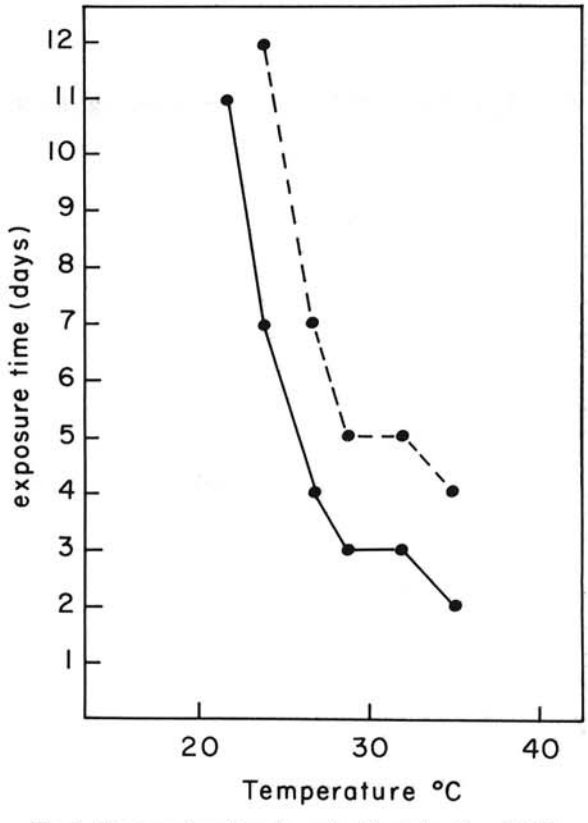

Fig. 3. Exposure time (days) required for induction of tipburn in 50% of mature detached Calmar lettuce heads subjected to constant high temperatures (solid line) or to alternating (broken line) high and low temperatures with 12 hr of cool, white fluorescent light daily. In alternating temperature treatments, plants were exposed on successive days to 24, 27, 29, 32, or 35 C at 47 ± 4% RH for 12-hr daily light period followed by 12 hr of exposure to 21 C at 70% RH during dark period. Each point represents average ratings of 40–43 heads in four repetitions.

Calmar and Calicel subjected to elevated temperatures were different. For example, Calicel, which has not been commercially accepted because of its low field tolerance to tipburn, had a significantly higher average tipburn severity index than did Calmar, with a relatively high level of field tolerance (Table 2). The differences between the two cultivars with respect to tipburn severity ratings after 3 and 5 days of exposure were significant ($P = 0.01$). As shown by standard deviation, however, the variability within each cultivar was relatively high.

Tipburn induction in the field.—Enclosing sections of beds in fields under polyethylene-covered frames resulted in increases in temperatures and RH inside the frames as well as temperatures inside heads. The daily mean ambient temperature and RH during a 6-day period ranged from 13 to 26.6 C and 50 to 90% RH, whereas inside the frames the range was from 16 to 34.6 C and 75 to 95% RH. The temperature averaged about 6.6 C higher inside the frames. Increase was significant in incidence and severity of tipburn inside versus outside the frames. The tipburn severity index and percentage of tipburn in heads outside the frames were 0.5 and 4%, respectively. Plants inside the frames for 1, 2, or 3 wk prior to harvest had tipburn severity indexes of 0.70, 0.92, and 0.81, respectively, and the corresponding percentages of tipburned heads were 42, 69, and 50%. Also, a close correlation occurred between the respective tipburn ratings of cultivars inside and outside the frames (Table 3). For example, Calicel, which is relatively susceptible, had a higher tipburn severity index both inside and outside the frames than did Calmar and Salinas, which are relatively tolerant. The differences between tipburn severity ratings inside and outside the frames for each cultivar were significant ($P = 0.01$).

TABLE 1. Effect of relative humidity on tipburn severity index and percentage of tipburned heads in mature detached lettuce heads subjected for 3 or 5 days to 30 C[a]

	Exposure time			
	3 days		5 days	
RH[b] (%)	Severity index[c]	Tipburned heads (%)	Severity index	Tipburned heads (%)
33	0.9	36	2.5	92
51	0.9	40	2.5	95
67	1.0	41	2.6	100
81	1.1	42	2.7	100
98	1.2	45	3.0	100

[a]Mature heads of Calmar cultivar were harvested from commercial field and placed in controlled environment chambers for 3 or 5 days; temperature was constant at 30 C with 12 hr of cool white light (18,000 lx) daily.

[b]RH = relative humidity.

[c]Severity index is mean rating based on scale from 0.5 (very slight) to 5.0 (severe) in damaged heads only. Each figure represents average rating of 52–59 heads in four repetitions. Among all treatments, only difference in severity index between 0.9 (33% RH) and 1.2 (98% RH) was significant ($P = 0.01$).

Relation between ambient temperature and head temperature.—Results from monitoring head and ambient temperatues at 1-hr intervals throughout a sunny August day (1975) in the Salinas Valley of California are shown in Fig. 4. Head temperature measurements in the early morning hours at various depths in the head were about the same as the ambient temperature, but within 3 hr after sunrise, the head temperatures increased up to 10 C or more above the ambient. The temperature of the outer 0.6- to 1.25-cm portions of the heads exceeded ambient temperature earlier and were maintained around 6 C above ambient temperature for more than 8 hr. Temperatures at 5- and 8.7-cm depths exceeded ambient for shorter periods and were never as high as those at shallower depths. The differences in temperature among individual heads were greater in the morning hours when the ambient temperature was rising than in the afternoon hours when ambient temperature was decreasing. In the late afternoon hours, immature plants cooled faster than did mature plants; the temperatures of all heads at the 2.5-cm depth were stable and close to the ambient temperature from 2300 to 0700 hr.

DISCUSSION

Consistent development of tipburn in both intact and detached mature heads in the field and in the laboratory by exposure to high constant or alternating temperatures

TABLE 2. Percentage of tipburn and severity index in mature detached heads of two lettuce cultivars subjected for 3 or 5 days to 30 C and 47 ± 4% relative humidity with 12 hr of cool white fluorescent light daily

		Exposure time			
		3 days		5 days	
Cultivars[a]		Severity index[b]	Tipburned heads (%)	Severity index[b]	Tipburned heads (%)
Calmar	Range	0–1.0	36	1.0–3.0	100
	Mean	0.37		2.1	
	SD	0.13		0.55	
Calicel	Range	0.5–2.0	83	2.0–5.0	100
	Mean	1.2		3.7	
	SD	0.45		0.82	

[a]Calicel, released in 1971, was not successful because of susceptibility to tipburn, whereas Calmar has greater tolerance than most other cultivars.

[b]Severity index is mean rating of heads with tipburn symptoms on scale from 0.5 (very slight) to 5.0 (severe). Each figure for mean severity index was calculated from ratings of 36 to 43 heads in four repetitions.

has provided evidence that temperature is an important influence in tipburn development. The effect of temperature on tipburn development was apparently cumulative, because under laboratory conditions, tipburn developed in detached heads about twice as fast under constant high temperatures (24 to 35 C) as under alternating high and low temperatures (12 hr of light at 24 to 35 C followed by 12 hr of dark at 21 C). Furthermore, the cumulative temperature (sums of hourly temperatures above 24 C during the exposure period) required for tipburn induction in 50% of the heads was fairly close in treatments of constant or alternating temperatures.

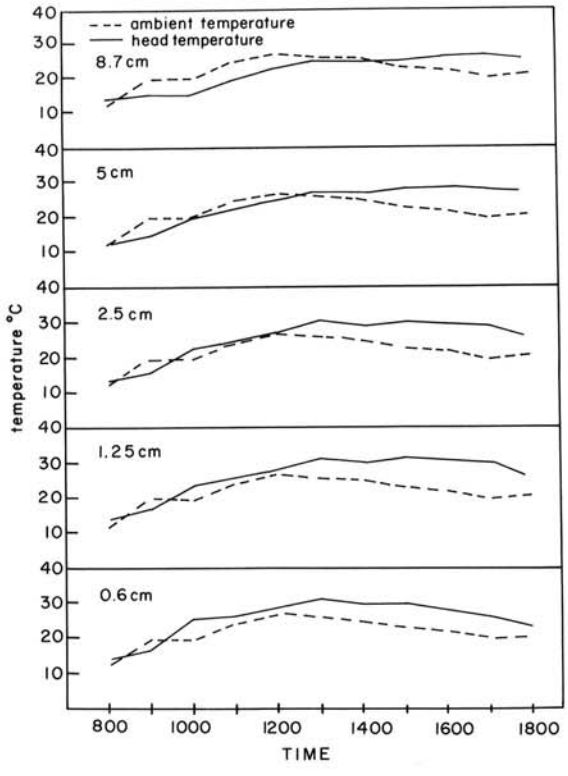

Fig. 4. Relation of ambient and head temperatures measured with thermocouple potentiometer at different depths from top of heads in field-grown Calmar lettuce at different times of day. Each point represents average of 20–25 readings from 20–25 heads during sunny day in August 1975 in field in Salinas Valley of California 2 days before harvest. Wind velocity at 0800, 0900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, and 1800 was 3.3, 2.6, 2.9, 7.8, 8.1, 7.7, 6.6, 8.6, 6.9, 4.2, and 3.1 m/sec^{-1}, respectively.

Our observation that temperatures inside heads in the field often are about 6 C higher than ambient during most daylight hours may be the reason why tipburn has occurred at times when ambient temperatures have not exceeded 24 C (the minimum temperature for tipburn induction under laboratory conditions). Lipton (12) reported that temperatures of lettuce heads in a field near Mendota, CA, exceeded ambient (10 cm aboveground) by as much as 7 C. Newhall (13) also reported that during bright sunshine, leaves of head lettuce may have temperatures between 11 and 14 C higher than ambient.

In our study, RH only slightly influenced tipburn development in mature detached heads. Intact plants at different stages of development in the field, however, might respond differently to RH. For example, Palzkill (15) reported that cabbage plants before heading (rosette stage) developed more tipburn under continuous high RH (82%) and illumination, but after head formation, more tipburn developed under continuous low RH (45%) and a diurnal light-dark cycle.

Despite a 20% increase in tipburn incidence in mature detached plants exposed to 30 C and 12 hr of light daily as compared with heads kept at 30 C in the dark, light did not influence tipburn development significantly. Furthermore, in field-grown plants, tipburn developed on the inner leaves, which were not exposed to direct sunlight.

We found that tipburn incidence and severity did not increase in harvested heads during a 12-day period if the temperature was maintained at 5 C. Lipton (11) also reported that percent of tipburned heads increased only slightly after harvest, even when lettuce was held several days at 10–20 C. Thus, tipburn is a disorder that develops in the field and increases little if at all in severity after harvest in heads stored under cool storage conditions.

Induction of tipburn by exposing detached heads to 30 C is a dependable, consistent method for evaluating relative tipburn tolerance of breeding lines and cultivars. Heretofore, evaluation was possible only when tipburn developed fortuitously in trial plantings in the field.

TABLE 3. Severity index and percentage of tipburned heads of four lettuce cultivars grown inside and outside plastic covered frames in field

	Av. tipburn severity index[a]		% of tipburned plants	
	Inside frames	Outside frames	Inside frames	Outside frames
Cal K60	1.02	0.00	52	0
Calmar	0.80	0.50	56	2
Salinas	0.91	0.50	63	3
Calicel	1.53	0.92	91	37

[a]Severity index is mean rating based on scale from 0.5 (very slight) to 5.0 (severe) of heads with tipburn symptoms. Plants in fields in Salinas Valley of California were enclosed for 6 days under frames covered with polyethylene sheets (1 × 1.2 × 3.3 m) at 12 to 14 days before harvest during August 1976. Average upper and lower ranges of outside ambient temperature and relative humidity (RH) were 13–26.6 C and 50–90% RH, whereas average ranges inside frames were 16–34.6 C and 75–95% RH. Each figure in table represents average rating of 37 to 44 heads in three repetitions.

LITERATURE CITED

1. ANDERSEN, E. M. 1946. Tipburn of lettuce. Effect of maturity, air and soil temperature and soil moisture tension. Cornell Univ. Agric. Exp. Stn. Bull. 829. 14 p.
2. ASHKAR, S. A., and S. K. RIES. 1971. Lettuce tipburn as related to nutrient imbalance and nitrogen composition. J. Am. Soc. Hortic. Sci. 96:448-452.
3. BANGERTH, F. 1973. Investigations upon Ca-related physiological disorders. Phytopathol. Z. 77:20-37.
4. BERT, J. S., JR., and S. HONMA. 1975. Effect of soil moisture and irrigation method on tipburn and edgeburn severity in greenhouse lettuce. J. Am. Soc. Hortic. Sci. 100:278-282.
5. BOHN, G. W. 1953. The important diseases of lettuce. pp. 417-425. *in*: U.S. Dept. Agric. Yearbook, A. Stefferud, Ed., U.S. Govt. Print. Off., Washington, DC. 972 p.
6. BOTTENBERG, G. E., and T. W. TIBBITTS. 1968. Lettuce growth and tipburn incidence under controlled humidity. (Abstr.). HortScience 3:124.
7. CANOVA, A. 1956. Imbrunimento marginale delle foglie di insalata. Ital. Agric. 93:623-625.
8. COX, E. F., J. M. T. McKEE, and A. S. DEARMAN. 1976. The effect of growth rate on tipburn occurrence in lettuce. J. Hortic. Sci. 51:297-309.
9. ENDE, J. VAN DEN, P. KOORNNEEF, and C. SONNEVELD. 1975. Osmotic pressure of the soil solution: Determination and effects on some glasshouse crops. Neth. J. Agric. Sci. 23:181-190.
10. KRAUSE, W. G. C. 1952. Tipburn on early lettuce. Commer. Grower 2971:1043-1044.
11. LIPTON, W. J. 1963. Postharvest changes in amount of tipburn of head lettuce and the effect of tipburn on incidence or decay. Plant Dis. Rep. 47:875-879.
12. LIPTON, W. J. 1971. Temperatures and net energy gain in a growing, mature head of lettuce. Agric. Meteorol. 8:429-437.
13. NEWHALL, A. G. 1925. The tipburn of head lettuce. Market Growers J. 36:358-359.
14. NEWHALL, A. G. 1929. Studies on tipburn of head lettuce. PhD thesis, Cornell Univ., Ithaca, NY. 139 p.
15. PALZKILL, D. A. 1976. Control of cabbage tipburn and calcium translocation by atmospheric humidity. PhD thesis, Univ. of Wisconsin, Madison. 60 p.
16. READ, M. 1972. Growth and tipburn of lettuce: Carbon dioxide enrichment at different light intensity and humidity levels, and rate of incorporation of carbon^{-14} assimilates into the latex. PhD thesis, Univ. of Wisconsin, Madison. 155 p.
17. SONNEVELD, C., and J. VAN DEN ENDE. 1969. De invloed van zout gietwater bij de slateelt onder glas. Tuinbouw Meded. 32:129-148.
18. THOMPSON, R. C. 1926. Tipburn of lettuce. Col. Exp. Stn. Bull. 311. 31 p.
19. TIBBITTS, T. W., and G. E. BOTTENBERG. 1971. Effects of temperature increases on tipburn injury of lettuce. (Abstr.). HortScience 6:306.
20. TIBBITTS, T. W., and R. R. RAO. 1968. Light intensity and duration in the development of lettuce tipburn. Proc. Am. Soc. Hortic. Sci. 93:454-461.
21. VAN DER KLOES, L. J. J. 1952. Hei randen van sla. Tuinbouw Meded. 15:125-139.
22. WESTERN, J. H. 1953. Water balance failure leads to tipburn. Grower 39:983.