Calcium Nutrition and Cultivar Influence Incidence of Tipburn of Collard

Jon R. Johnson¹

Clemson University Sandhill Research and Education Center Columbia, SC 29224

Additional index words. *Brassica oleracea*, *Acephala* group, mineral nutrition

Abstract. The collard (*Brassica oleracea*, *Acephala* group) cultivar Vates was more susceptible than 'Blue Max' to tipburn in sand-culture and field studies. Calcium concentrations in young leaves were similar for both cultivars. 'Blue Max' appears to require a lower Ca concentration in young leaves than 'Vates' for normal growth. In sand-culture studies, increasing the Ca level in nutrient solution to 3 mM or higher decreased tipburn in 'Vates'. 'Blue Max' did not develop tipburn regardless of Ca level. Increasing the Ca level in nutrient solution increased Ca concentration in young and old leaves for both cultivars. Soil application of CaSO_4 or foliar application of $\text{Ca}(\text{NO}_3)_2$ or CaCl_2 did not decrease occurrence of tipburn in Vates', presumably because these treatments did not increase Ca concentrations in young leaves.

Tipburn of younger leaves of collard was observed during Summer 1988 in commercial fields in central South Carolina. The inward cupping and marginal burn of the young collard leaves appeared to be the same as those associated with tipburn of cabbage, cauliflower, and lettuce. Studies on cabbage (Maynard et al., 1965), cauliflower (Maynard et al., 1981), and lettuce (Collier and Tibbitts, 1984; Thibodeau and Minotti, 1969; Yanagi and Bullock, 1983) indicated that tipburn was caused by a localized Ca deficiency in the tip of the leaf. Soil application of CaSO_4 or foliar application of $\text{Ca}(\text{NO}_3)_2$ or CaCl_2 has been found to be effective in controlling tipburn of cauliflower (Gruesbeck and Zandstra, 1988).

Collard is a cool-season crop grown primarily in the spring and fall in the southeastern United States, but interest in growing collard during the summer is increasing due

to the high gross return that can be obtained during this period. High temperature and humidity are common in the southeastern United States during the summer. High-temperature stress has been found to increase the incidence and degree of tipburn of lettuce (Yanagi and Bullock, 1983). High relative humidity has been determined to promote development of tipburn of cabbage (Palzkill et al., 1980). There is no information on the influence of Ca nutrition and cultivar on tipburn of collards grown under high temperatures. The objectives of these studies were to determine the influences of Ca nutrition and cultivar on the incidence of tipburn and leaf Ca concentrations of collards grown under high-temperature stress.

Sand-culture experiments. In two greenhouse experiments, collard plants were grown in quartz sand in 28-cm-diameter (15 liters) pots. The experimental design was a split-plot, with cultivars ('Vates' and 'Blue Max') as main plots and Ca treatments as subplots. Treatments were replicated five times. An experimental unit consisted of one plant in a pot. In Expt. 1, 4-week-old transplants in the three-leaf stage were planted on 10 Oct. 1988. Treatments were initiated on 12 Oct. 1988 and terminated with harvest on 17 Nov. 1988. All nutrient solutions contained (mg-liter⁻¹);

Received for publication 17 Nov. 1989. Technical Contribution no. 3030 of the South Carolina Agricultural Experiment Station. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

¹Assistant Professor.

Table 1. Severity of tipburn and Ca concentration in collard leaves as influenced by cultivar and Ca level in nutrient solution. (Sand culture, Expt. 1.)^a

Cultivar	Ca level (mM)	Tipburn severity (rating) ^b	Ca concn in leaves (% dry wt) ^c	
			Young	Old
Vates	1	3.8	0.61	1.27
	3	1.4	1.53	3.09
	5	1.0	2.58	4.32
	10	1.8	2.78	4.95
		L**Q***	L**Q*	L**Q**
Blue Max	1	1.0	0.60	1.18
	3	1.0	1.53	2.95
	5	1.0	2.15	3.88
	10	1.0	2.91	4.81
		NS	L**Q**	L**Q**

^aCultivar × Ca interaction significant for tipburn rating and nonsignificant for Ca concentration in young and old leaves.

^bVisual tipburn rating on a scale of 1 = no tipburn and 5 = severe tipburn.

^cYoung leaves = terminal five leaves, old leaves = all leaves older than fifth leaf from terminal.

^dEffects linear (L) or quadratic (Q) nonsignificant (NS) or significant at $P = 0.05$ (*) or 0.01 (**).

Table 2. Plant dry weight and Ca concentration of collard leaves as influenced by Ca level in nutrient solution and by cultivar. (Sand culture, Expt. 2.)^a

Cultivar	Ca level (mM)	Dry wt (g/plant)	Ca concn in leaves (% dry wt) ^b	
			Young	Old
Vates	1	30.77	0.51	1.33
	5	34.88	1.55	4.00
	10	35.98	2.04	5.28
	1 then 10*	40.37	2.12	4.08
		NS	0.50	0.45
LSD 0.05 ^w				
Blue Max	1	40.52	0.58	1.21
	5	48.75	1.60	3.65
	10	53.30	1.98	4.71
	1 then 10*	46.34	2.21	3.62
		7.31	0.22	0.33
LSD 0.05 ^w				

^aCultivar × Ca interaction nonsignificant for tipburn rating, plant dry weight, and Ca concentration in young and old leaves.

^bYoung leaves = terminal five leaves, old leaves = all leaves older than fifth leaf from terminal.

^cOne mM Ca for the first 3 weeks of the study and 10 mM Ca thereafter through harvest.

^dMean separation between Ca treatment means within a cultivar by LSD at $P = 0.05$. Nonsignificant (NS) difference based on F test for difference between Ca treatments within a cultivar.

Table 3. Severity of tipburn and Ca concentration in collard leaves as influenced by Ca treatment and cultivar in the field. (Expt. 4.)^a

Factor	Tipburn severity (rating) ^b	Ca concn in leaves (% dry wt) ^c	
		Young	Old
Cultivar			
Vates	3.0 a	0.72 a	1.59 a
Blue Max	1.0 b	0.56 b	1.18 b
Ca applied ^w			
None	2.0 a	0.59 c	1.28 c
CaSO ₄ , soil	1.5 a	0.69 a	1.53 a
Ca(NO ₃) ₂ , foliar	2.0 a	0.62 bc	1.40 b
CaCl ₂ , foliar	2.0 a	0.65 ab	1.33 bc

^aMean separation within columns, cultivars, and Ca treatments by LSD, $P = 0.05$.

^bVisual tipburn rating on a scale of 1 = no tipburn and 5 = severe tipburn.

^cYoung leaves = terminal five leaves, old leaves = eighth leaf from the terminal.

^dCaSO₄ applied preplant broadcast at 200 kg Ca/ha and incorporated into the soil. Ca(NO₃)₂ and CaCl₂ applied as weekly foliar sprays at 4 kg Ca/ha per application. Foliar Ca treatments were applied five times.

234 K, 31 P, 49 Mg, 0.5 B, 0.5 Mn, 0.05 Zn, 0.02 Cu, 0.01 Mo, and 1 Fe. Sequestrene 330 (iron chelate) was the source of Fe. Solutions (800 ml) containing 1, 3, 5, or 10 mM Ca, all with 15 mM NO₃, were added to the pots three times per week for the first 2 weeks after transplanting. On days between Ca applications, pots received 800

ml of deionized water. The amount of Ca solution and deionized water applied was increased to 1 liter per day at 2 weeks from transplanting and maintained at that level until harvest. Average daily maxima and minima in the greenhouse were 31C and 24C, respectively. In Expt. 2, Ca treatments were 1, 5, and 10 mM Ca for the experiment's

duration. Application of nutrient solution and deionized water was the same as in Expt. 1. An additional treatment was 1 mM Ca for the initial 3 weeks of the study and 10 mM Ca thereafter. Five-week-old transplants in the four-leaf stage were planted 26 Jan. 1988. Treatments were initiated on 1 Feb. 1989 and terminated on 6 Mar. 1988. Daily maxima and minima in the greenhouse averaged 32C and 22C, respectively.

Dry weights of young leaves (the terminal five leaves) and old leaves (all leaves older than the fifth leaf from the terminal bud) were recorded. At the completion of the studies, tipburn was rated, with 1 = no tipburn and 5 = severe tipburn. Tissue samples from the young and old leaves were dried at 70C and then ground to pass through a 20-mesh screen. Leaf Ca concentrations were determined by atomic absorption spectroscopy.

Field experiments. Two field experiments were conducted with 'Vates' and 'Blue Max' collards grown on a Lakeland sandy soil (Thermic typic quartzipsamments) at Clemson Experiment Station, Columbia, S. C., during Summer 1989. The native soil Ca level before application of limestone was 340 kg-ha⁻¹, which is considered to be in the low range. Dolomitic limestone was applied at 560 kg-ha⁻¹ 6 weeks before initiation of the studies. Preplant broadcast fertilizer (10N-4.4P-8.3K) that contained 1% Ca was applied at 560 kg-ha⁻¹. Plants were transplanted when they were in the three-leaf stage (4 weeks old). Plot size was 1.8 m wide x 12.2 m long. Each plot contained two rows of collards with 71 cm between rows and 46 cm between plants in the row. The experiment was a split-plot in a randomized complete block design, with cultivars as main plots and Ca fertilization method as subplots. Treatment combinations were replicated four times. A nonionic spray adjuvant (alkyl polyoxylkane ether) at 540 ml-ha⁻¹ was applied with all foliar Ca solutions. Foliar Ca solutions were applied with a tractor-mounted sprayer calibrated to apply 450 liters · ha⁻¹ at a pressure of 193 kPa. In Expt. 3, transplants were planted on 18 May 1989. Calcium treatments were: 1) control, 2) preplant broadcast soil application of Ca at 200 kg-ha⁻¹ from CaSO₄, 3) three weekly foliar applications each of 4 kg Ca/ha as Ca(NO₃)₂ starting 2 weeks after transplanting, and 4) one foliar application of Ca(NO₃)₂ as in treatment 3 applied 4 weeks after transplanting. Average air maxima and minima were 31C and 19C, respectively. Collards were provided with 25 mm of water per week from a combination of rainfall and irrigation to prevent moisture stress. Plants were harvested 37 days after transplanting.

General experimental procedure for Expt. 4 was the same as that described for Expt. 3. Transplants were planted on 28 June 1989. Calcium treatments for Expt. 4 included: 1) control, 2) preplant soil application of Ca at 200 kg-ha⁻¹ from CaSO₄, 3) foliar applications of 4 kg Ca/ha per application as Ca(NO₃)₂, and 4) foliar applications of 4 kg Ca/ha per application as CaCl₂. The foliar

Ca treatments were applied five times on a weekly basis starting 10 days after transplanting. Average air maxima and minima were 32C and 21C, respectively. Plants were harvested 42 days after transplanting.

Data collected at harvest included number of tipburned plants per hectare and Ca concentrations of whole-leaf tissue samples from young and old leaves. Young leaves consisted of the terminal five leaves. Old leaf samples were the eighth leaf from the terminal bud of the plant. Leaf samples were washed in deionized water before preparation for nutrient analysis. Tissue samples were analyzed using the same method as described for sand-culture studies.

Data analysis. Data from all studies were tested by analysis of variance to determine the significance of main effects of cultivar and Ca treatment and to determine the presence of interaction between these factors. Data from Expt. 1 were subjected to regression analysis, by cultivar, to determine the response to Ca level in the nutrient solution. Calcium treatment means within cultivar in Expt. 2 and means from Expts. 3 and 4 were separated by LSD test, $P = 0.05$.

Sand culture. Increasing the Ca level from 1 to 10 mM increased Ca concentration in young and old leaves for both cultivars (Table 1). Increasing Ca concentration from 1 to 3 mM decreased incidence of tipburn for 'Vates', with further increases in Ca concentration having no effect (Table 1). Tipburn was absent on 'Blue Max' at any Ca concentration. Calcium concentration in young leaves was similar for both cultivars at each Ca treatment level. Calcium concentrations in older leaves were consistently higher for 'Vates' than for 'Blue Max'.

In Expt. 2, Ca concentration in young and old leaves increased as nutrient solution Ca level was increased from 1 to 10 mM. However, plant dry weight of 'Vates' was not influenced by the Ca level in the nutrient solution, but that of 'Blue Max' plants supplied with 1 mM Ca was lower than for those supplied with 5 or 10 mM Ca. Nutrient solution Ca level had no influence on incidence of tipburn for either cultivar (rating range, 1.0 to 2.8 for 'Vates', 1.0 for all 'Blue Max'). 'Vates' had a higher incidence of tipburn than 'Blue Max' (tipburn rating of 1.8 vs. 1.0, respectively) when averaged over the four Ca treatments (Table 2). Cultivars did not differ for Ca concentration in young leaves

('Vates' -1.55% and 'Blue Max' -1.59%, $P > F = 0.59$) when averaged over the four Ca treatments. 'Vates' had a slightly higher Ca concentration in the old leaves than did 'Blue Max' (3.67% and 3.30%, respectively, $P > F = 0.06$) when averaged over the four Ca treatments.

Calcium concentrations in young leaves of 'Vates' were similar for plants supplied with 10 mM for the entire study to those supplied with 1 mM Ca at the beginning and 10 mM at the end (Table 2). For 'Blue Max', the Ca concentrations of young leaves were lower for plants supplied with 10 mM Ca for the entire study than for those supplied with 1 mM Ca at the beginning of the study and 10 mM at the end of the study. Calcium concentrations in old leaves were higher for plants of both cultivars supplied with 10 mM Ca for the entire study than those supplied with 1 mM Ca at the beginning and 10 mM at the end.

Field plantings. In Expt. 3, 49% of the 'Vates' plants showed tipburn vs. < 1% for 'Blue Max' plants (significant difference at $P = 0.01$). Calcium treatment had no influence on incidence of tipburn, possibly because of an adequate amount of Ca in the soil. Calcium concentrations of young and old leaves (0.65% and 1.4%, respectively) were not influenced by cultivar or Ca treatments. 'Vates' also was more susceptible to tipburn than 'Blue Max' in Expt. 4 (Table 3). Again, Ca treatments did not influence the severity of tipburn. Calcium concentrations in young and old leaves were higher for 'Vates' than for 'Blue Max'.

Soil and foliar Ca applications did not influence the severity of tipburn of collards in the field studies, most likely because a sufficient amount of Ca was supplied from the soil (native Ca, dolomitic limestone, and preplant fertilizer). Adequate water (rainfall/irrigation), provided to prevent moisture stress, may also have limited the response to Ca applications.

The critical leaf tissue Ca content for collard, used by most laboratories in the southeastern United States, is 3% to 4% (most recently matured leaf). 'Vates' plants, grown in sand culture, produced the highest plant dry weight with Ca concentrations in young and old leaves of at least 0.51% and 1.33% (dry-weight basis), respectively (Table 2); for 'Blue Max', the analogous Ca concentrations were 1.60% and 3.65%, respectively

(Table 2). Calcium concentration of the old leaves (most recently matured) was in the range of 1.28% to 1.53% for the field studies (Table 3). Optimal plant growth of collards, from these studies, was obtained with leaf Ca concentrations lower than the accepted critical leaf tissue Ca content.

Calcium concentrations in young leaves of 'Vates' were similar to or higher than for 'Blue Max'. Because tipburn of other *Brassica* spp., such as cabbage, is caused by a localized Ca deficiency in the tip of young leaves, it would be expected that Ca concentration would be lower for 'Vates' than 'Blue Max'. However, 'Vates' may require a higher Ca concentration than 'Blue Max' for normal growth, especially under high-temperature stress.

'Vates' was more susceptible to tipburn than 'Blue Max' in sand and field culture. Cultivars of cauliflower were found to differ in Ca efficiency (Hochmuth, 1984). Appropriate cultivar selection appears to be more effective than Ca applications in controlling tipburn of collards grown during the summer in the southeastern United States.

Literature Cited

- Collier, G.F. and T.W. Tibbitts. 1984. Effects of relative humidity and root temperature on calcium concentration and tipburn development in lettuce. *J. Amer. Soc. Hort. Sci.* 109(2):128-131.
- Gruesbeck, R.V. and B.H. Zandstra. 1988. Calcium applications overcome tipburn in cauliflower. *HortScience* 23(3):827-828.
- Hochmuth, G.J. 1984. Variation in calcium efficiency among strains of cauliflower. *J. Amer. Soc. Hort. Sci.* 109(5):667-672.
- Maynard, D. N., B. Gersten, and H.F. Vernell. 1965. The distribution of calcium as related to internal tipburn, variety, and calcium nutrition in cabbage. *Proc. Amer. Soc. Hort. Sci.* 86:392-396.
- Maynard, D. N., D.C. Warner, and J.C. Howell. 1981. Cauliflower leaf tipburn: A calcium deficiency disorder. *HortScience* 16(2):193-195.
- Palzkill, D. A., T.W. Tibbitts, and B.E. Struckmeyer. 1980. High relative humidity promotes tipburn on young cabbage plants. *HortScience* 15(5):659-660.
- Thibodeau, P.O. and P.L. Minotti. 1969. The influence of calcium on the development of lettuce tipburn. *J. Amer. Soc. Hort. Sci.* 94(4):372-376.
- Yanagi, A.A. and R.M. Bullock. 1983. Factors involved in the development of tipburn in crisphead lettuce in Hawaii. *J. Amer. Soc. Hort. Sci.* 108(2):234-237.