

## EFFECTS OF CA ON SEVERAL STORAGE DISORDERS OF WINTER CABBAGE<sup>1</sup>

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Atmospheres low in oxygen ( $O_2$ ) have been reported to influence the development of storage disorders affecting head leaves of cabbage (*Brassica oleracea* L. var *capitata* L.). Isenberg et al. (9) reported a reduction in "pepper spot disease", which was not clearly distinguished between "black speck" (12) and cabbage "mosaic" (10). Bohling and Hansen (3) mentioned that low  $O_2$  concentrations inhibited a kind of necrosis of the outer leaves of cabbage without identifying the disorder. Geeson and Browne (7) reported a reduction or the elimination by CA storage of a non-microbial leaf necrosis disorder named "pepper-spotting". Walsh et al. (13) observed that an atmosphere of 3%  $O_2$  and 5%  $CO_2$  had little effect in the control of "black speck" which they considered as synonym of "pepper spot" and "grey speck", under the basis of Cox review (5).

In those reports, the several names and synonyms used to describe the symptoms observed on stored cabbage create confusion. Bérard et al. (2) identified clearly grey speck disease (11) and vein streaking (1, 6, 8) as two distinct storage disorders of cabbage influenced by CA. Grey speck disease, a disorder affecting mainly the basal part of the dorsal leaf blade with irregular and coalescent grey specks, was completely controlled by exposure to 2.5%  $O_2$  and 5%  $CO_2$  during a storage period of 24 weeks (2); similarly, vein streaking, a disorder characterized by brown markings on the ventral side of midrib and lateral veins, was reduced greatly by the same CA conditions (2). In that study, the progressive development of the two disorders in refrigeration (RS) and CA storages was not however followed.

The aim of the present study is to investigate further the evolution of grey speck disease and vein streaking in RS and CA storages with some regards on the variability within season. For this purpose, the two disorders were studied at intervals and in parallel with common criteria of senescence in cabbage, such as degreening, leaf abscission and loss of dormancy.

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### Experimental procedures

Twenty-five cultivars of winter cabbage were grown in 1982 and 1983 at the Experimental Farm of Agriculture Canada at l'Acadie, Québec. In both years, seedlings were started in cold frame in late May and transplanted in the field by the end of June, in a randomized complete-block design with 3 replications. Spacing and cultural practices were as reported by Chong and Bérard (4).

Cabbage heads were harvested between October 18 and 23. Within each replicate and cultivar, heads of similar size were selected, picked and trimmed off their loose wrapper leaves, before being grouped in uniform samples of 3 heads each and placed in plastic mesh bags. Within 4 hours after harvest, samples were moved in RS at  $1 \pm 1^{\circ}\text{C}$  and  $92 \pm 5\%$  RH. Parts of the refrigerated samples were moved in commercial CA rooms of similar temperature and humidity, that were sealed 8 to 10 days after harvest to obtain a gas composition of 2.5%  $\text{O}_2$  and 5%  $\text{CO}_2$  after an  $\text{O}_2$  pulldown period of 16 to 30 days. The  $\text{CO}_2$  of the CA rooms was scrubbed with lime or activated carbon.

In 1982-83, cabbage samples were removed from CA at intervals of  $44 \pm 6$  days or after  $175 \pm 1$  days. In 1983-84, they were removed from CA after a period of  $122 \pm 7$  days from harvest. Over each storage season, the CA treatment was followed by a post-CA period of 42 or 49 days where the CA samples were returned to and held with the plain RS samples. Cabbages held in RS were sampled at the same time as the CA ones, and also at intervals of  $44 \pm 6$  days in 1983-84.

Typical symptoms of grey speck disease and vein streaking were noted while trimming the outer-head leaves of cabbages of each sample, and observing their dorsal and ventral sides. The 2 disorders were recorded on an individual head basis regardless of the severity of symptoms on each, and expressed in percentage of the total heads handled. With this method, the mean incidence per treatment had an accuracy of 11%. In 1983-84, the severity of vein streaking was additionally measured using the method and the 6-class severity chart described by Bérard et al. (1), which had a mean accuracy of 4%.

Degreening measurements were made on the outer-head leaves before trimming using a 10-class colour chart to quantify individually each head of a sample before conversion to a global degreening index per sample (0 = full green leaves; 50% = green outer-head leaves with areas of yellow and brown; 100% = full brown outer-head leaves). Leaf abscission was recorded when one or more leaves of a head showed an abscission line or full separation from the stem. Loss of dormancy was noted when apical and/or lateral buds showed signs of regrowth with or without head cracking. Leaf abscission and loss of dormancy were recorded on an individual head basis before conversion to percent of total heads handled. Heads were considered suitable for fresh market only if they were free from trimming cuts and from outside or inside head damage after removal of the first 3 outer-head leaves.

### Evolution in storage

During the 1982-83 and 1983-84 storage seasons, the progressive evolution of grey speck disease and vein streaking was studied on 2 cvs having a good keepability, the cv Safekeeper susceptible to both disorders, and the cv Mercury F<sub>1</sub> susceptible to vein streaking only (2). In 1983-84, the cv Excel of a relatively poor keepability and susceptible to vein streaking only (2), was studied in addition to the two cvs listed above.

In both storage seasons, grey speck disease was completely controlled by CA; such phenomenon was demonstrated clearly with the susceptible cv Safekeeper that was frequently affected by grey speck disease in RS (Tables 1 and 2). This beneficial effect of CA was still evident after a post-CA period of 42 or 49 days in RS (Tables 1 and 2).

In the 1982-83 storage season, the vein streaking symptoms noted on cvs Safekeeper and Mercury F<sub>1</sub> held in RS were completely controlled by CA and did not show 42 days after removal from CA (Table 1). In 1983-84, the CA treatment was less effective in the control of the incidence of vein streaking, but the symptoms observed in CA were much less severe than in RS (Table 2). These slight symptoms noted on the CA samples 122 days after harvest persisted during the post-CA period of 49 days in plain RS, but did not increase perceptibly either in incidence or in severity (Table 2).

### Variability within season of the effect of CA

In addition to this study on the evolution in storage of grey speck disease and vein streaking, more than 20 cvs of winter cabbage were studied in CA and RS. In 1982-83, the cultivars were evaluated after  $175 \pm 1$  days of storage and in 1983-84 after  $122 \pm 7$  days. In both storage seasons, a period of 4 to 10 days in RS followed the CA treatment.

As shown from the cv Safekeeper above reported, the other cultivars susceptible to grey speck disease in RS did not show any symptoms after CA exposure in 1982-83 (Table 3). However, in 1983-84, trace symptoms of grey speck disease were noted after CA exposure on cvs Danish Ballhead and Hybrid H, and symptoms more severe than in RS were observed on cv Superslaw (Table 3; Fig. 1). These observations showed that the variable efficiencies of CA in controlling grey speck disease was depending largely on seasons and cultivars.

In 1982-83, the control of vein streaking by CA was either complete or partial but evident. A slight incidence of 11% was noted on cvs Houston Evergreen, Storage Green and Winterkeeper after 175 days of storage (Table 3). In 1983-84, the control of vein streaking by CA on the same cultivars was much less effective (Table 3): 22 to 33% of the heads were commonly injured after 122 days of storage, and occasionally 67 to 81% of them showed symptoms, as did cvs April Green and Storage Green. For these last two cvs, the incidence of vein streaking in CA was even greater than in RS. But when the severity of the disorder was considered, only cv April Green showed damages in CA worst than in RS (Table 3).

For most of the other cultivars evaluated in 1983-84, the frequency and the severity of vein streaking was reduced by CA (Table 3) but never eliminated as commonly found in 1982-83. The effect of CA in controlling vein streaking varied therefore considerably within seasons and cultivars.

This effect of season on the incidence of vein streaking in CA was less perceptible in RS. Cabbage cvs Safekeeper and Mercury F<sub>1</sub> held in RS for periods of 38, 80, 122, 171 and 213 days in 1982-83 had an incidence of vein streaking closely similar to that of the 1983-84 storage season (Tables 1 vs 2), although CA was not similarly effective in controlling the disorder each year.

### **Senescence and evolution of disorders in storage**

In 1982-83, cabbages held in RS for 38 days had an incidence of grey speck disease and vein streaking ranged from 44 to 56%, but did not show yet any trace of yellowing on their outer-head leaves, either any trace of abscission or any loss of dormancy (Table 1). In 1982-83, cabbages held for 42 days in RS after CA exposure, developed degreening and abscission of their outer-head leaves during the post-CA period, but failed to develop grey speck disease and vein streaking symptoms (Table 1).

In 1983-84, cv Excel showed an incidence and a severity of vein streaking quite similar to cvs Safekeeper and Mercury F<sub>1</sub>, although losing its dormancy much earlier during the storage season (Table 2). In RS during the 1982-83 and 1983-84 storage seasons, grey speck disease and vein streaking affected closely the same percentage of heads although degreening and abscission of the outer-head leaves progressed less rapidly in 1982-83 than in 1983-84 (Tables 1 vs 2). However, that season 1982-83, where CA was more effective in controlling vein streaking, was the season where senescence progressed less rapidly in RS and during the post-CA period, as indicated by degreening and abscission (Tables 1 vs 2).

From these observations, it is concluded that the development of grey speck disease and vein streaking is not closely associated with the general senescence of cabbage. The development of symptoms in RS before day 38, and the relative stability of the two disorders in term of incidence or severity thereafter suggest that grey speck disease and vein streaking are early storage disorders. In this regard, the development of grey speck disease and vein streaking is similar to that of "black speck" reported to appear at stomata level soon after entrance in refrigerated storage (12).

### **Fresh marketability of affected cabbages**

In this 2-year study, the damages caused by grey speck disease and vein streaking were generally limited to the outer-head leaves of the cabbage heads. Therefore, the trimming of these outer-head leaves allowed the removal of undesirable symptoms and permitted to keep the

fresh market quality of the heads. Such phenomenon was clearly observable in 1982-83, where a high incidence of grey speck disease and vein streaking during the first 171 days of storage did not affect the fresh marketability of the cabbages (Table 1). In 1983-84, most of the cabbage heads held for 213 days in storage were not suitable for fresh market (Table 2) because of storage rots and of a loss of dormancy in the cv Excel rather than grey speck disease and vein streaking incidence. Grey speck disease and vein streaking have nevertheless been reported to cause economic losses in other situations (2, 11). In such cases the heads were usually not totally affected, but the cost of labor for trimming extra head leaves and the resulting greater losses of marketable weight did not justify marketing poor quality product at reduced price.

### Conclusion

According to the results of this study, the following conclusions can be drawn:

1. CA usually reduced or eliminated the incidence of grey speck disease, but may accentuate its severity occasionally.
2. CA reduced the incidence and the severity of vein streaking, but not constantly.
3. The beneficial effect of CA in controlling of the two disorders persisted after removal from CA.
4. The efficiency of CA in controlling these two disorders varied greatly within season.
5. CA delayed degreening considerably, eliminated abscission and loss of dormancy during the first 122 or 171 days of storage.
6. The development, in storage, of grey speck disease and vein streaking is an early storage process not closely related to the general senescence of cabbage.

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Table 1. Evolution in refrigerated (RS), in controlled atmosphere (CA) storages and 42 days after CA (underlined numbers) of grey speck disease and vein streaking on 2 cultivars of winter cabbage, in parallel with several criteria of senescence observed in 1982-83.

Disorders and Senescence criteria	Storage treatments <sup>2</sup>	Days in storage from harvest											
		cv Safekeeper						cv Mercury F <sub>1</sub>					
		1	38	80	122	171	213	1	38	80	122	171	213
Grey speck disease (% of heads)	RS	0	44	67	100	100	89	0	0	0	0	0	0
	CA		0	0	0	0	<u>0</u>		0	0	0	0	<u>0</u>
Vein streaking (% of heads)	RS	0	56	89	89	100	89	0	56	11	56	89	67
	CA		0	0	0	0	<u>0</u>		0	0	0	0	<u>0</u>
Degreening (color index (%))	RS	0	0	15	38	39	47	0	0	5	22	14	37
	CA		0	0	5	2	<u>36</u>		0	0	0	0	<u>15</u>
Abscission (% of heads)	RS	0	0	0	44	56	56	0	0	44	56	67	78
	CA		0	0	0	0	<u>33</u>		0	0	11	0	<u>22</u>
Loss of dormancy (% of heads)	RS	0	0	0	0	0	0	0	0	0	0	0	0
	CA		0	0	0	0	<u>0</u>		0	0	0	0	<u>0</u>
Fresh marketability (% of heads)	RS	100	100	100	100	100	89	100	100	100	100	100	89
	CA		100	100	100	100	<u>89</u>		100	100	100	100	<u>89</u>

<sup>2</sup> Initiation of the CA treatment 8 days after harvest.

Table 2. Evolution in refrigerated (RS), in controlled atmosphere (CA) storages and 49 days after CA (underlined numbers) of grey speck disease and vein streaking on 3 cultivars of winter cabbage, in parallel with several criteria of senescence observed in 1983-84.

Disorders and Senescence criteria	Storage treatments <sup>2</sup>	Days in storage from harvest																	
		cv Safekeeper						cv Mercury F <sub>1</sub>						cv. Excel					
		1	38	80	122	171	213	1	38	80	122	171	213	1	38	80	122	171	213
Grey speck disease (% of heads)	RS	0	0	100	78	78	89	0	0	0	0	0	0	0	0	0	0	0	0
	CA				0	<u>0</u>					0	<u>0</u>					0	<u>0</u>	
Vein streaking (% of heads)	RS	0	67	89	67	78	78	0	56	67	33	78	78	0	44	56	56	56	33
	CA				22	<u>33</u>					44	<u>33</u>					0	<u>11</u>	
(severity index (%))	RS	0	23	30	29	32	18	0	18	22	22	21	15	0	13	15	19	20	3
	CA				4	<u>7</u>					15	<u>3</u>					0	<u>3</u>	
Degreening (color index (%))	RS	0	1	17	30	57	83	0	5	16	40	56	82	0	4	24	42	85	80
	CA				1	<u>58</u>					0	<u>24</u>					1	<u>56</u>	
Abscission (% of heads)	RS	0	0	44	33	100	100	0	0	22	78	100	100	0	33	44	100	100	100
	CA				0	<u>100</u>					0	100					0	<u>100</u>	
Loss of dormancy (% of heads)	RS	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	56	100	100
	CA				0	<u>0</u>					0	<u>0</u>					0	<u>22</u>	
Fresh marketability (% of heads)	RS	100	100	100	78	11	22	100	100	100	100	22	0	100	100	78	56	0	0
	CA				100	<u>0</u>					89	<u>44</u>					100	0	

<sup>2</sup> Initiation of the CA treatment 10 days after harvest.



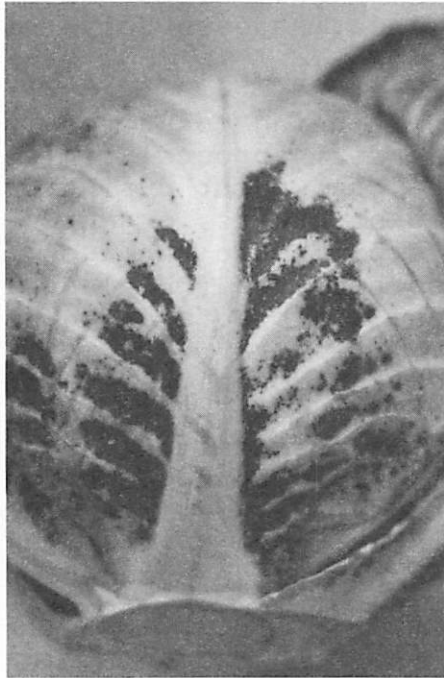
Table 3. Cultivars susceptibility to grey speck disease and vein streaking after storage in refrigerated (RS) and controlled atmosphere (CA) storages in 1982-83<sup>z</sup> and 1983-84<sup>y</sup>.

Cultivars	Grey speck disease				Vein streaking				Severity Index (%)	
	Incidence (%)				Incidence (%)				1983-84	
	1982-83		1983-84		1982-83		1983-84		RS	CA
	RS	CA	RS	CA	RS	CA	RS	CA	RS	CA
April Green	22	0	0	0	100	0	33	67	11	20
Bartolo	11	0	11	0	89	0	87	33	32	11
Custodian	-x	-	89	0	-	-	67	11	24	3
Danish Ballhead	0	0	0	11	44	0	44	22	14	7
Decema Extra	0	0	-	-	22	0	-	-	-	-
Eastern Ballhead	0	0	11	0	78	0	22	0	8	0
Evergreen Ballhead	0	0	0	0	56	0	56	0	17	0
Excel	0	0	11	0	44	0	44	22	16	5
Green Winter	0	0	0	0	33	0	33	33	19	8
Hidena	0	0	-	-	67	0	-	-	-	-
Hitoma	0	0	-	-	11	0	-	-	-	-
Houston Evergreen	0	0	-	-	67	11	-	-	-	-
Hybrid H	-	-	22	11	-	-	33	11	11	4
Mercury F <sub>1</sub>	0	0	11	0	56	0	56	33	14	10
Penn State Ballhead	0	0	0	0	0	0	0	0	0	0
Polinius	0	0	0	0	78	0	89	11	22	8
Quick Storage Green	0	0	0	0	78	0	33	11	10	7
Rio-Verde	-	-	0	0	-	-	11	0	1	0
Safekeeper	56	0	100	0	100	0	100	33	36	7
Sanibel	-	-	0	0	-	-	11	11	3	11
Slawdena	0	0	-	-	44	0	-	-	-	-
Storage Green	44	0	81	0	100	11	56	81	30	29
Superslaw	-	-	33	22	-	-	56	22	26	7
Ultra Green	22	0	22	0	100	0	67	33	31	10
Winterkeeper	11	0	0	0	67	11	56	22	15	5

<sup>z</sup> 175 ± 1 days of storage from harvest; CA with the first 8 and the last 4 to 6 days in RS.

<sup>y</sup> 122 ± 7 days of storage from harvest; CA with the first 10 and the last 4 to 10 days in RS.

x Cultivar not tested that storage season.



**Fig. 1** Cabbage head of cv Superslaw severely affected by grey speck disease after CA storage in 1983-84.