and temperature conditions between the treatments (Brown and Brown, 1992).

In conclusion, foam mulch maintained its integrity for the entire growing season and provided similar weed suppression to the black plastic mulch. Mulch color did not affect weed suppression. This is probably because regardless of color the foam mulch did not allow light penetration and likely served as a physical barrier impeding weed emergence.

Mulch color but not mulch type affected early, ripe fruit, and total yield. Yields in blue foam mulch were greater than in the other treatments. Tomato fruit yields in black foam and black plastic mulches were similar. Further research is needed to confirm the effect of blue color on tomato yield and to compare blue foam mulch with blue plastic mulch. Microenvironment monitoring is also needed under foam mulch to determine its effects on the crop environment and to understand how foam mulch impacts tomato growth and yield.

Foam mulch is currently being commercialized for use in high-value situations. Foam mulch may also have potential for use in organic vegetable production. At this stage, foam mulch is more costly than plastic mulch and is uneconomical to use on larger conventionally-produced, commercial plantings of tomato or basil. We expect that as application technology is improved and the use of foam mulch becomes more common, the price of foam mulch will decrease and its use in larger vegetable plantings will increase.

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# Genotypic Variation in Chilling Sensitivity of Mature-green Bananas and Plantains


Keri L. Morrelli,[1]

Betty M. Hess-Pierce,[2] and

Adel A. Kader[3]



**ADDITIONAL INDEX WORDS.** ***Musa paradisiaca*, chilling injury**



**SUMMARY. The variation in chilling sensitivity of mature-green specialty bananas (*Musa paradisiaca* var. *sapientum*) and plantains (*Musa paradisiaca* var. *paradisiaca*) was examined using four cultivars of bananas and one plantain cultivar stored under various time and temperature combinations. Cold storage for 1 day at 5.0, 7.2, or 10.0 °C (41, 45, or 50 °F) resulted in acceptable fruit quality for up to 8 days at 20.0 °C (68 °F) for 'Petite' and 'Red Macabu' bananas and 'Dominico Harton' plantains. 'Grand Nain' and 'Yangambi' bananas were considered unmarketable due to moderate to severe graying after 8 days at 20.0 °C when fruit were previously stored for 1 day at 5.0 or 7.2 °C. Storage for 3 days at 10.0 °C was acceptable for all cultivars tested, however 5 days at 10.0 °C resulted in moderate to severe browning and graying of the 'Grand Nain' fruit. The traditional Cavendish-type, 'Grand Nain', as well as 'Petite' and 'Yangambi', required temperatures greater than 10.0 °C for a 7-day storage duration while 'Red Macabu' bananas could be safely stored for 7 days at 10.0 °C. Plantains could be stored at 7.2 °C for 7 days without visible chilling injury symptoms. The storage of specialty bananas and plantains at or above their minimum safe temperatures resulted in improved uniformity of ripening and overall quality of the fruit due to a decrease in chilling injury symptoms.**



Department of Pomology, University of California, One Shields Avenue, Davis, CA 95616.



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[1]Graduate student.

[2]Staff research associate.

[3]Professor and corresponding author; e-mail aakader@ucdavis.edu.

Chilling injury (CI) in bananas, as well as many other tropical and subtropical fruits and vegetables, is a postharvest disorder which can result in great losses in the quality and shelf life of the fruit. Classic symptoms of CI in bananas are subepidermal vascular browning, peel discoloration, delayed or abnormal ripening, and sometimes failure to ripen.

Experimentation to determine the temperatures at which various banana cultivars should be stored and transported, primarily in relation to avoiding CI during transit, was initiated in the early 1930s. 'Gros Michel' and 'Dwarf Cavendish' bananas were well suited for storage up to 18 d at 11.7 °C (53 °F) (Wardlaw, 1961). Wardlaw and McGuire (1933) reported that when 'Giant Governor' ('Giant Cavendish') fruit were stored for 16 d at 14.4 °C (58 °F), the fruit was superior in color to that of fruit stored at 11.7 °C. 'Fillbasket', a ladyfinger-type banana, could withstand 16 d at 11.7 °C and continue normal ripening and color development when ripened at 21.1 °C (70 °F), while cultivars such as 'Bumulan', 'Masak Hijau' and 'Giant Fig' showed slight signs of chilling after 18 d at 13.3 °C (56 °F) (Wardlaw and McGuire, 1933). 'Lacatan' (Abilay, 1968; Fidler, 1965; Wardlaw and McGuire, 1933) and 'Poyo' bananas also required higher storage and shipping temperatures of 12.8 to 13.9 °C (55 to 57 °F) to avoid CI (Wardlaw, 1961). Abou Aziz et al. (1976) found that 'Maghrabi' bananas were less susceptible to CI than 'Hindi' bananas.

Standard Fruit Company (1959, in Wardlaw 1972) confirmed that CI in bananas was related to the temperature and exposure time in 'Golden Beauty' and 'Giant Cavendish' fruit. As storage temperatures approached the minimum safe temperatures for each cultivar, the duration of time before CI symptoms were visible was extended. Fidler (1968) commented that CI may be latent in occurrence, such that the lower the storage temperature the greater the damage; however, the visible damage that occurs may develop less rapidly at low temperatures compared to slightly warmer temperatures. 'Giant Cavendish' stored for the same duration at 10.0, 8.9, or 7.8 °C (50, 48, or 46 °F) could result in slight, moderate, or severe chilling symptoms, respectively (Wardlaw, 1972). Storage of 'Dwarf Cavendish' bananas for 2 d at 7.2 °C resulted in a 1-d delay in color development when fruit were ripened; however, there were no additional signs of CI on the fruit. When bananas were stored for 4 d at 7.2 °C, there was no effect on the ripening of the pulp; however, there was a considerable delay in the color development of the peel (Young et al., 1932). Wardlaw and McGuire (1931) found that 'Gros Michel' bananas developed CI symptoms when stored for 9 d at 10.6 °C (51 °F) and 14 d at 11.1 °C (52 °F), while no damage was observed when fruit were held for 16 to 20 d at 11.7 °C.

The focus of this study was to determine the minimum safe temperature for 7 d storage (simulated transport time from production areas to U.S.) of five specialty banana and plantain cultivars.

## Materials and methods

**Plant material.** Mature-green 'Grand Nain' and 'Petite' bananas and 'Dominico Harton' plantains were obtained for the first experiment and 'Yangambi' and 'Red Macabu' bananas were obtained for the second experiment from Dole Fruit International, Costa Rica, via air transport. In both experiments fruit were harvested at mature green, 3/4-round grade, and shipped the following day, arriving within 7 d of harvest. Upon arrival, the bananas were separated into individual fingers which were sorted, removing damaged and defective fingers. The crown of each finger was dipped for 30 s into 100 μL·L$^{-1}$ (ppm) chlorinated water solution and allowed to dry. Plantains arrived as single fingers. The crown of each finger was trimmed with a knife and the cut end was dipped for 30 s into 100 μL·L$^{-1}$ chlorinated water solution and allowed to dry. For each cultivar, fruits were separated into 15 groups of five fruit each. Within each group, fruit were numbered consecutively 1 through 5 and placed into a perforated polyethylene bag to prevent the alteration of the atmosphere inside the bag. The bags were then closed at their top openings.

**Storage temperatures and durations.** Fruit were stored at 5.0, 7.2, and 10.0 °C for 1, 3, 5, or 7 d. At the end of each storage period, the fruit were visually evaluated and transferred to 20.0 °C [75% to 85% relative humidity (RH)] for ripening.

**Ripening.** Fruit were placed at 20.0 °C in 1-m$^3$ stainless-steel tanks that were ventilated with a continuous flow of humidified air (90% to 95% RH) and 100 μL·L$^{-1}$ ethylene ($C_2H_4$) for 48 h. Ethylene concentrations were measured using a gas chromatograph (Carle model 211; EG&G Engineering, Tulsa, Okla.) equipped with a flame ionization detector and stainless steel column packed with activated alumina at 80 °C (176 °F). After the 48-h treatment period, the fruit were removed from the tanks and the bags and placed on trays at 20.0 °C. External fruit quality was evaluated every other day for up to 8 d at 20.0 °C to assure development of any latent CI symptoms (Fidler, 1968).

**Quality evaluations.** Visual evaluations of peel color, browning, and graying were made. Scoring for color was determined using a 1-7 color scoring scale as described by Von Loesecke (1950): 1 = hard green; 2 = soft green; 3 = more green than yellow; 4 = more yellow than green; 5 = yellow with green tips; 6 = full yellow; and 7 = yellow with brown spots. Color development in 'Yangambi' and 'Red Macabu' bananas was scored on a 1 to 6 color scale because fruit never developed brown spots (based on previous observation). Peel browning was described as vascular browning within the peel when slight and throughout the peel when severe and extreme in occurrence. Peel browning was most visible when the fruit was green. Peel graying was described as dulling in the yellow color development of the peel. Peel browning and graying were scored separately using the following five-point scale: 1 = none, 2 = slight (limit of marketability), 3 = moderate, 4 = severe, 5 = extreme discoloration.

**Statistical analysis.** Statistical significance by analysis of variance was determined using SAS System for Windows Release 8.02 (SAS institute, Cary, N.C.). Significant differences among means was done by least significant difference (LSD) at $P < 0.05$.

## Results

Initial observations of 15 fruit from each cultivar indicated that no CI occurred during transit from Costa Rica. The initial fruit from each cultivar were evaluated upon arrival for peel color and browning. Immediately after the initial evaluation the fruit were ripened and reevaluated after 2 d and every other day for a total of 8 d. Postripened fruit of all cultivars showed no chilling symptoms and ripened to a color stage 6 in less than 8 d (line 1 in Table 1).

**Cold storage effects on color development.** No significant differences were observed in color advancement for any of the cultivars and any of the time

**Table 1. Days for each banana and plantain cultivars to reach color stage 6 during storage at 20.0 °C (68 °F) following indicated cold storage conditions and ripening.**

| Storage conditions | | Days to reach color stage 6[z] | | | | |
|---|---|---|---|---|---|---|
| Duration (d) | Temp (°C)[x] | 'Grand Nain' | 'Petite' | 'Yangambi' | 'Red Macabu' | Plantain |
| 0 | | 5 | 5 | 6 | 5 | 5 |
| 1 | 5.0 | 8 | 8 | 10 | 8 | 6 |
| | 7.2 | 6 | 6 | 10 | 8 | 4 |
| | 10.0 | 6 | 4 | 10 | 8 | 4 |
| 3 | 5.0 | 8 | 8 | 8 | 8 | 6 |
| | 7.2 | 8 | 8 | 8 | 6 | 6 |
| | 10.0 | 8 | 6 | 8 | 6 | 4 |
| 5 | 5.0 | >8 | 8 | >8 | >8 | 6 |
| | 7.2 | 8 | >8 | >8 | 8 | 6 |
| | 10.0 | 8 | 8 | >8 | 8 | 6 |
| 7 | 5.0 | 8 | ---[y] | >8 | >8 | 6 |
| | 7.2 | 8 | --- | >8 | 8 | 4 |
| | 10.0 | 8 | --- | 8 | 6 | 4 |

[z]Color stage 6, as described by Von Loesecke (1950) is when the peel of the fruit reaches full yellow in color.
[y]Data not available.
[x]°F = 1.8 (°C) + 32.

temperature combinations upon removal from storage, with all fruit remaining at a color stage 1 ($P < 0.05$) (data not shown). Initial fruit held at 20.0 °C and treated with ethylene, ripened to color stage 6 in 5 d for 'Grand Nain', 'Petite', 'Red Macabu', and plantains and 6 d for 'Yangambi' fruit (Table 1).

When 'Grand Nain' bananas were stored for 1 d at 7.2 or 10.0 °C, the fruit reached color stage 6 after 6 d at 20.0 °C, while fruit stored for 1, 3, or 7 d at 5.0 °C, and 3, 5 or 7 d at 7.2 or 10.0 °C required 8 d to reach the same stage (Table 1). Fruit held at 5.0 °C for 5 d failed to reach color stage 6 after 8 d at 20.0 °C.

When 'Petite' bananas were stored for 1 d at 7.2 °C or 3 d at 10.0 °C, the fruit reached color stage 6 after 6 d at 20.0 °C. Fruit stored for 1 d at 10.0 °C required only 4 d to reach color stage 6. Fruits stored for 5 d at 7.2 °C or 7 d at 5.0 or 7.2 °C failed to ripen to full yellow color by day 8 of the evaluations at 20.0 °C (Table 1).

'Yangambi' bananas showed the greatest delay in color development after exposure to low temperatures for only 1 d when compared to all other cultivars tested. All time/temperature combinations resulted in a delay in color advancement when compared to the initial fruit. Fruit stored for 1 or 5 d at 5.0, 7.2, or 10.0 °C or 7 d at 5.0 or 7.2 °C failed to reach color stage 6 after 8 d at 20.0 °C (Table 1).

For 'Red Macabu' bananas, all time/temperature combinations resulted in a delay in color advancement when compared to the initial fruit. Fruit stored for 5 or 7 d at 5.0 °C failed to reach a color stage 6 after 8 d at 20.0 °C (Table 1).

Plantains stored at 5.0 °C for 1, 3, 5 or 7 d required 6 d to reach a color stage 6. Plantains kept at 7.2 °C for 1 or 7 d or at 10.0 °C for 1, 3, or 7 d ripened to color stage 6 in 4 d, which was 1 d faster than the initial fruit (Table 1).

**COLD STORAGE EFFECTS ON BROWNING.** Storing 'Grand Nain' bananas for 1 d at 5.0, 7.2, or 10.0 °C resulted in no browning of the peel immediately after storage; however, there was slight discoloration in bananas stored 1 d at 5.0 or 10.0 °C after 8 d at 20.0 °C (Table 2). Fruit stored for 3 d at 5.0 or 7.2 °C had noticeable browning upon removal from cold storage. Storage at 5.0 °C for 5 d or longer resulted in extreme brown discoloration of the peel upon removal from cold storage. Fruit stored for 5 d at 7.2 °C had moderate brown discoloration after removal from cold storage and after 8 d at 20.0 °C there was an increase in the severity of the discoloration. After 8 d at 20.0 °C, 'Grand Nain' bananas previously stored for 5 d at 10.0 °C had significantly less browning than those that were stored 5 d at 5.0 or 7.2 °C. When fruit were stored for 7 d at 7.2 °C, there was severe browning of the peel, while fruit stored at 10.0 °C was free of peel discoloration immediately after cold storage. After 8 d at 20.0 °C, fruit held previously at 10.0 °C for 7 d showed signs of peel browning; however, discoloration was slight and significantly less than the fruit stored 7 d at 5.0 or 7.2 °C.

Storage of 'Petite' bananas for 1 d at 5.0, 7.2, or 10.0 °C resulted in no observable peel browning for up to 8 d at 20.0 °C (Table 2). Fruit stored for 3 or more d at 5.0 °C exhibited extreme browning of the peel upon removal from cold storage. In addition, fruit stored for 3 or more d at 7.2 °C showed moderate to severe browning. Fruit stored for 3, 5, or 7 d at 10.0 °C had no observable browning of the peel.

'Yangambi' bananas stored for 1 d at 5.0, 7.2, or 10.0 °C showed no immediate signs of peel browning upon removal from cold storage; however, slight browning was observed after 8 d at 20.0 °C (Table 2). Storage for 3 d at 5.0 and 7.2 °C resulted in peel browning upon removal from cold storage, which increased to extreme and severe levels of discoloration after 8 d at 20.0 °C, respectively. Storing fruit for 5 or 7 d at 5.0 or 7.2 °C resulted in extreme discoloration of the peel. Fruit stored at 10.0 °C for 5 or 7 d had slight peel browning. After 8 d at 20.0 °C, fruit were only slightly discolored due to browning but were still considered marketable (scores ≤2 are considered marketable).

For up to 7 d of storage at ≤10.0 °C no peel browning was observed on 'Red Macabu' bananas immediately after storage (Table 2). Fruit stored at 5.0 °C for 5 and 7 d had moderate discoloration after 8 d at 20.0 °C, which was significantly greater when compared to fruit stored at 7.2 and 10.0 °C for the same durations.

Browning of the peel was first observed in plantain fruit stored for 7 d at 5.0 °C (Table 2). However, even though statistically significant, discoloration was minimal even after 8 d at 20.0 °C.

**COLD STORAGE EFFECTS ON GRAYING.**

Table 2. Browning scores for bananas and plantains after 1, 3, 5, or 7 d at 5.0, 7.2, and 10.0 °C (41, 45, and 50 °F).

| Cultivar | Temp (°C) | Immediately after storage (d) | | | | After an additional 8 d at 20.0 °C (68 °F) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 3 | 5 | 7 | 1 + 8 | 3 + 8 | 5 + 8 | 7 + 8 |
| Grand Nain | 5.0 | 1.0 a[z,y] | 2.0 b | 5.0 e | 5.0 e | 1.6 bc | 4.5 f | 5.0 g | 5.0 g |
| | 7.2 | 1.0 a | 2.1 b | 3.1 c | 4.0 d | 1.0 a | 3.0 de | 3.9 e | 4.0 e |
| | 10.0 | 1.0 a | 1.0 a | 1.8 b | 1.2 a | 1.5 b | 1.0 a | 2.2 d | 1.7 c |
| Petite | 5.0 | 1.0 a | 5.0 d | 5.0 d | 5.0 d | 1.0 a | 5.0 d | 5.0 d | 5.0 d |
| | 7.2 | 1.0 a | 3.0 a | 4.0 c | 3.3 b | 1.0 a | 4.2 b | 4.5 c | 4.5 c |
| | 10.0 | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a |
| Yangambi | 5.0 | 1.0 a | 2.5 c | 4.9 e | 5.0 e | 1.6 c | 4.5 e | 5.0 f | 5.0 f |
| | 7.2 | 1.0 a | 2.1 c | 4.6 de | 4.4 d | 1.5 bc | 4.3 d | 5.0 f | 5.0 f |
| | 10.0 | 1.0 a | 1.3 ab | 1.2 ab | 1.5 b | 1.2 a | 1.3 ab | 1.7 c | 1.6 c |
| Red Macabu | 5.0 | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.5 ab | 3.5 e | 3.6 e |
| | 7.2 | 1.0 a | 1.3 b | 1.0 a | 1.0 a | 1.0 a | 1.1 a | 2.3 cd | 2.8 d |
| | 10.0 | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.8 bc | 2.0 bc |
| Plantain | 5.0 | 1.0 a | 1.0 a | 1.0 a | 1.4 b | 1.0 a | 1.0 a | 1.0 a | 1.6 b |
| | 7.2 | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a |
| | 10.0 | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a | 1.0 a |

[z]Browning scores are based on a five-point scale (1 = no discoloration, 5 = extreme discoloration).
[y]Means followed by the same letter within each cultivar and evaluation period (immediately after storage and after an additional 8 d at 20.0 °C) are not significant at $P = 0.05$.

Graying of the peel did not become visible until after the fruit began to turn yellow.

In 'Grand Nain' bananas, fruit stored at 10.0 °C had significantly less graying (Table 3). Only a slight degree of gray discoloration was observed when fruit were stored for 1, 3, or 7 d at 10.0 °C and ripened for 8 d at 20.0 °C. Fruit stored at 5.0 or 7.2 °C showed moderate, severe or extreme discoloration after 8 d at 20.0 °C for all storage durations.

In 'Petite', fruit stored at 10.0 °C had no detectable graying (Table 3). Graying of the 'Petite' fruit upon ripening was slight as a result of cold storage for 1 d at 5.0 or 7.2 °C. Fruit stored for 3 d or longer at 5.0 or 7.2 °C was considered unmarketable due to browning of the peel (Table 2 and 3), which made scoring of the peel for graying extremely difficult.

'Yangambi' bananas were highly susceptible to graying. Fruit stored at 10.0 °C had significantly less graying when compared to fruit stored at 5.0 or 7.2 °C (Table 3). Fruit stored for 1, 3, 5, or 7 d at 5.0 or 7.2 °C showed moderate to extreme discoloration from graying when observed after 8 d at 20.0 °C.

When 'Red Macabu' bananas were stored at 5.0, 7.2, or 10.0 °C for 1 or 3 d, there was no significant graying (Table 3). Fruit stored for 5 d at 5.0 °C had more graying compared to the other treatments; however, the fruit was only slightly marred by this defect. All fruit stored at ≤10.0 °C for 7 d showed slight graying of the ripe fruit.

There was no observed graying in plantains stored for 1, 3, 5, or 7 d at 5.0, 7.2, or 10.0 °C (Table 3).

## Discussion

Sensitivity to chilling-induced damage varies among cultivars of banana (Abou Aziz et al., 1976; New and Marriott, 1974; Wardlaw and McGuire, 1933). Specialty banana cultivars and plantains appear to be more tolerant of temperatures below 13 °C than the traditional Cavendish-type bananas, and thus have lower minimum safe temperatures for transport and storage. In the present study, 'Grand Nain' fruit that were stored for 7 d have a minimum safe storage temperature of greater than 10.0 °C, based on unacceptable browning and graying of the peel. 'Petite' fruit must be stored at temperatures greater than 10.0 °C for the fruit to be acceptable after 7 d cold storage. Unacceptability was due to browning and graying of the peel and a delayed rate of ripening. 'Yangambi' fruit could be stored at 10.0 °C for 7 d; however, this appears to be a marginal storage temperature because fruit of this cultivar in general took longer than 8 d at 20.0 °C to reach a color stage 6. 'Red Macabu' fruit could be stored at 10.0 °C for 7 d and still ripen to a highly acceptable product, free of CI symptoms. Plantains can be stored at 5.0 °C for 7 d and still ripen to acceptable quality with minimal CI symptoms, while

Table 3. Peel graying scores for bananas and plantains stored for 1, 3, 5, or 7 d at 5.0, 7.2, and 10.0 °C (41, 45, 50 °F) and ripened for 8 d at 20.0 °C (68 °F).

| Cultivar | Temp ( °C) | After 8 d at 20.0 °C (d) | | | |
|---|---|---|---|---|---|
| | | 1 + 8 | 3 + 8 | 5 + 8 | 7 + 8 |
| Grand Nain | 5.0 | 3.3 d[z,y] | 4.0 e | 5.0 f | 4.0 e |
| | 7.2 | 3.0 c | 3.5 d | 2.0 b | 4.0 e |
| | 10.0 | 1.4 a | 1.5 a | 3.5 d | 1.4 a |
| Petite | 5.0 | 1.8 b | 5.0 f | ---[x] | --- |
| | 7.2 | 1.0 a | 4.5 e | 3.9 d | 3.5 c |
| | 10.0 | 1.0 a | 1.0 a | 1.0 a | 1.0 a |
| Yangambi | 5.0 | 3.3 c | 4.5 e | 5.0 f | 5.0 f |
| | 7.2 | 3.5 d | 4.5 e | 5.0 f | 4.9 f |
| | 10.0 | 1.0 a | 1.5 b | 1.5 b | 1.6 b |
| Red Macabu | 5.0 | 1.0 a | 1.1 a | 2.8 b | 2.4 b |
| | 7.2 | 1.0 a | 1.1 a | 1.5 a | 2.8 b |
| | 10.0 | 1.0 a | 1.3 a | 1.5 a | 2.3 b |
| Plantain | 5.0 | 1.0 a | 1.0 a | 1.0 a | 1.0 a |
| | 7.2 | 1.0 a | 1.0 a | 1.0 a | 1.0 a |
| | 10.0 | 1.0 a | 1.0 a | 1.0 a | 1.0 a |

[z]Graying scores are based on a five-point scale (1 = no discoloration, 5 = extreme discoloration).
[y]Means followed by the same letter within each cultivar are not significant at $P = 0.05$.
[x]Petite bananas kept at 5.0 °C were discarded after 3 d because of severe chilling injury.

plantains stored at 7.2 °C showed no observable signs of CI after 7 d storage.

Brown and gray discolorations are both visible CI symptoms that appear to be interrelated. Fruit that showed signs of browning also showed varying degrees of graying of the peel as the fruit began to ripen in all cultivar-temperature-time combinations except for plantains and 'Yangambi' bananas stored for 1 d at 10.0 °C. There are many reasons for why browning and graying occur in combination. At low temperatures, phenolic constituents, primarily dopamine in the peel as well as in the pulp (Kanazawa and Sakakibara, 2000), can be oxidized (Murata and Ku, 1966) to brown substances resulting in the brown discoloration observed in the experiment. The disorder first appears within the vascular bundles of the peel (Murata, 1969) and then radiates outward as the disorder increases in severity. In cases where CI is minimal, resulting in only a slight graying of the peel, dull yellow color in appearance, browning may not be observed upon removal from cold temperature. 'Grand Nain' and 'Yangambi' fruit stored for 1 d at 5.0 or 7.2 °C and 'Red Macabu' fruit stored for 5 d at 5.0 °C showed no signs of browning upon removal from cold temperatures; however, after 8 d at 20.0 °C the fruit showed slight to moderate gray discoloration. It is highly likely that during ripening as chlorophyll is degraded, revealing yellow carotenoids, the oxidized phenolic constituents remain resulting in the gray peel discoloration. In cases of slight discoloration, it is possible that the dark, oxidized constituents are not visible until peel color change from green to yellow has occurred. In severe cases, it has been suggested that low temperature storage reduces or inhibits the activity of chlorophyllase, which is responsible for the degreening of the peel, resulting in delayed, nonuniform, or complete inhibition of yellow color development (Mootoo and Murr, 1990). Delays in ripening as seen in all treatments with 'Yangambi' fruit, may be attributed to increased sensitivity of a specific chlorophyllase to low temperatures.

In general cold temperature storage increased the number of days required for each cultivar to reach color stage 6. Young et al. (1932) also found that slight chilling of *Musa* spp. resulted in delayed ripening with no other visible signs of chilling damage. In the case of plantains stored at 7.2 °C for 1 or 7 d or at 10.0 °C for 1, 3, or 7 d, there was a decrease in the number of d required for the fruit to reach color stage 6. CI can manifest itself as abnormal ripening and in this case the result is an increase in the rate of ripening. Similar results have been observed in grapefruit (*Citrus paradisi*) (Cooper et al., 1969) and avocado (*Persea americana*) (Eaks, 1983), where low temperature storage results in increased production of ethylene and increased respiration rate, resulting in increased rates of ripening.

Relative humidity plays an important role in the appearance of peel discoloration and chilling symptoms (Abilay, 1968). Mattei (1978) reported that at 12 °C (53.6 °F), CI symptoms were observed after 2 d in 75% RH and after 6 d at 85% RH. Browning of the peel can be confused with desiccation following abrasion of the peel and in extreme cases the resulting symptoms may be indistinguishable between the two. Since fruit were kept in about 75% to 85% RH during the cold storage treatment periods it is likely that some of the browning observed, mainly severe and extreme browning scores, were in part due to moderate desiccation of the peel at the same time that chilling was occurring. Graying of the peel, seen in many of the cultivars tested, could in addition be also be attributed to low RH during storage (Broughton and Wu, 1979).

Seven days of storage, representing the shipping time from Central America to North American ports, is considerably shorter that the 21 d shipping time required for transport to northern Europe and Asia. It is likely that the minimum storage temperatures that were determined in this study will not be optimal for longer transport and/ or storage durations. Also, the effects of preharvest climatic conditions must be considered. Further studies are needed to investigate the effects of temperatures less than 13 °C (55.4 °F) in combination with controlled atmospheres. These storage regimes could prove beneficial over a 21-d storage period, as well as to allow for storage of fruit at even lower temperatures during a 7-d period, thus allowing for greater ease in the shipping of mixed loads of produce.

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