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Solar Radiation Influences Solar Yellowing, Chilling Injury, and ACC Accumulation in 'Honey Dew' Melons

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Abstract. **'Honey Dew' melon fruits (*Cucumis melo* L.) matured under filters that transmitted between 1% and 100% of total solar and between 2% and 100% of ultraviolet (UV) radiation. Solar yellowing (SY) developed predominantly on top of the melons and increased as their exposure to direct solar radiation increased. Degree of exposure to solar radiation during maturation and susceptibility to postharvest development of chilling injury (CI) during 17 days at 2.5°C were inversely related. SY and CI also were inversely related. Levels of ACC in the skin were low at harvest and unaffected by degree of exposure to solar radiation. Reducing the exposure to the sun by half nearly doubled the concentration of ACC during chilling; complete shading resulted in little additional increase in ACC. After chilling, the skin from the bottom of the melons consistently contained slightly more ACC than that from the top. Chemical name used: 1-aminocyclopropane-1-carboxylic acid (ACC).**

The postharvest development of chilling injury (CI) of 'Honey Dew' (*Cucumis melo* L.) muskmelons is inversely related to the incidence of solar yellowing (SY) on fruit skin (6). This intriguing relationship led us to investigate a) whether the degree of exposure of the melons to solar radiation influences the development of SY and whether it also influences the susceptibility of the melons to CI during subsequent storage at a low temperature; b) whether the UV-B (290 to 320 nm) portion of the spectrum contributes to the development of SY and thus influences postharvest development of CI; c) the relation between exposure of the melons to solar radiation and the changes in the concentration of ACC during a chilling exposure, because it has been demonstrated that the presence of SY and chilling-induced accumulation of ACC are inversely related (9). A preliminary report of some of the results has been presented (5).

Materials and Methods

We grew the 'Honey Dew' melons in our Fresno, Calif. laboratory plots (lat 36°46'N, elevation ≈100 m) during the 1982 through 1985 seasons. The plants were grown in hills 50 or 75 cm apart (first 2 and last 2 years, respectively) and were furrow-irrigated at 2½- to 3-week intervals. Harvests were in July and early August.

Melons were tagged at 7 ± 1 days after anthesis. The correct time for tagging was judged by size and appearance of the fruit (10). When the tagged melons were 27 ± 1 days post-anthesis, we removed the other maturing fruit from the vines, carefully rearranged the vines to expose the test melons to solar radiation, and marked the top of each one.

Six shading treatments were used. The controls (FE) were fully exposed to solar radiation. Four of the radiation filters were attached to tent-like frames (7); these were transparent Tedlar (100BG 15UT polyvinylfluoride film; DuPont de Nemours, Wilmington, Del.), a single layer of 12-mesh (S12) or 60-mesh (S60) cheesecloth or a double layer (D60) of the latter. For Tedlar, the triangular sides of the tents were left open to avoid excessive heating within. For the sixth treatment, we placed a melon into a double layer of paper bags (DB). The bags rested horizontally on the ground and the upper two corners of the closed end were cut off to provide ventilation; the open end was folded over and held in place with spring clips. The outer bags were white during the first 2 years and brown thereafter, because the melons in the white bags remained slightly cooler than those of the other treatments. All treatments were applied to successive suitable melons in the row, each group of six melons being a replication. We used eight to 15 replicates per year, depending on availability of melons.

Transmissions for the various filters are given in Table 1. We measured solar radiation (SR) at ground level for each treatment by means of a Weston sunlight illumination meter (Model 756).

Table 1. Proportion of total solar and UV flux that reached 'Honey Dew' melons maturing under various radiation filters.

Filter		Proportion of unfiltered energy flux[z]	
Type	Symbol	Total (%)	Ultraviolet (%)
None	FE	100	100
Tedlar, transparent film	---	78	16
Cheesecloth, 12-mesh	S12	73	67
60-mesh, single	S60	54	46
60-mesh, double	D60	30	23
Paper bag, double	DB	1	2

[z]Values are based on means of measurements on 15 days at about solar noon. Actual mean values were 691 $W \cdot m^{-2}$ for total and 28 $W \cdot m^{-2}$ for UV radiation.

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These readings were 74% of those measured with an Eppley PSP pyranometer (2), which was located 1.8 m above ground level and ≈10 km north of the melon plots. UV flux was estimated with a Model J-260 (1982 and 1983) or UVX (1985) digital radiometer with sensors calibrated at 297 nm or 310 nm, respectively (both from Ultraviolet Products, San Gabriel, Calif.). The calibration curve supplied by the manufacturer for the radiometer shows maximal and nearly constant response between 300 and 325 nm. We present data for 1985 only, because the UVX model provided more consistent data than the J-260. The relative values, however, were similar. Instrument problems invalidated the readings in 1984.

Temperatures of one maturing melon from each treatment were monitored by means of thermocouples that had been inserted 1 to 2 mm below the top surface and parallel to the skin. Air temperature outside the tents was measured similarly and at the level of the melons. We used a "Brown Electronik" multipoint recorder (Honeywell, Minneapolis) in 1982 and 1983 and a Grant multipoint cassette recorder (Model CR50; Science/Electronics, Dayton, Ohio) in 1984 and 1985.

Only melons of ripeness 1 or 1.5 [minimum horticultural maturity and fully mature, respectively (10)] were used. We recorded the presence of SY and of solar injury on a scale of 1 = none to 9 = extreme (3). The melons were then placed into fiberboard boxes that were covered with a perforated plastic bag and stored 17 ± 2 days at 2.5° ± 0.5°C. We evaluated the degree of CI by extent and intensity of discoloration (8) for each fruit after storage and noted which portion of the melon was affected. The results for SY and CI are given in terms of a severity factor (SF = percent incidence × severity rating) for each treatment (7). We also sampled (1984 and 1985 only) skin portions from the top and bottom of six melons from each of three treatments (fully exposed; covered with one layer of 60-mesh cheesecloth; in double bag) for ACC content (9) before and after chilling.

Results

Temperatures. The mean maximum readings just under the skin of the melons ranged from 36° to 43°C during 1982 and 1983 and from 41° to 48° in 1984 and 1985. Temperatures generally increased with degree of exposure to solar radiation (data not shown). Melons that matured in the bags were slightly cooler than any of the others when the outer bag was white, but they were at the same temperature as those covered with two layers of 60-mesh cheesecloth when the outer bag was brown. All minima were above 10°, which is substantially above the highest likely chilling temperature (5°) for 'Honey Dew' melons (4).

Solar yellowing. SY developed predominantly on or near the top of melons, i.e., the area most directly exposed to the sun. Of 133 occurrences, SY appeared on the top half of the melons in 93%. Additionally, SY clearly increased as exposure of the melons to solar radiation increased (Fig. 1).

Chilling injury. Full exposure of maturing 'Honey Dew' melon fruits to solar radiation substantially reduced the seriousness of CI during their subsequent storage at 2.5°C relative to melons that were completely shaded by paper bags (Fig. 1B; treatment DB). Partially shaded melons were intermediate in their susceptibility to CI.

Symptoms of CI overwhelmingly (90% of occurrences) developed on the lower two-thirds of the melon surface. The ground spot and the area immediately surrounding it were particularly susceptible. CI developed only or mainly in the ground spot area in 30% of affected fruit, although it represents 10% or less of the surface. Additionally, visible symptoms never developed exclusively on the top one-third on any melon. Melons exposed to considerable solar radiation (those fully exposed, under Tedlar or one layer of 12-mesh or 60-mesh cheesecloth) behaved similarily. The top one-third of the surface developed CI in 4% or fewer of these fruits, even when the lower two-thirds of the surface was affected. In contrast, the top surface of 17% of the mostly shaded melons (two layers of 60-mesh cheesecloth) and 25% of the completely shaded ones (double bags) developed CI.

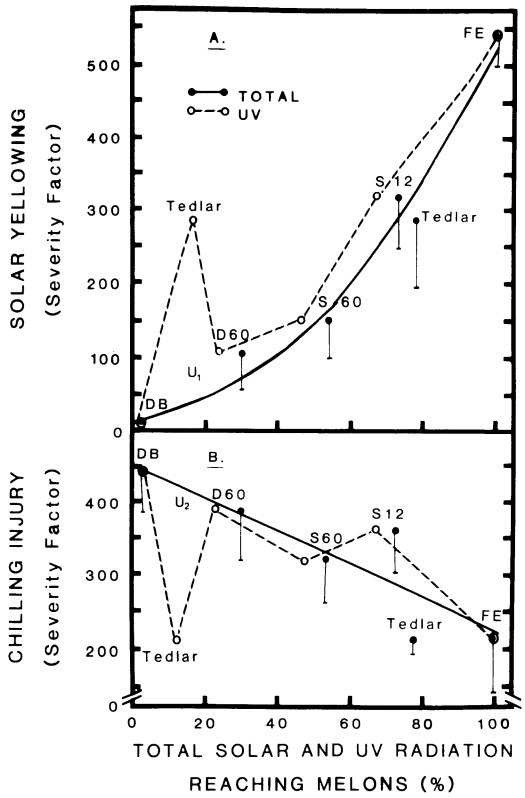

Fig. 1. Occurrence of solar yellowing (**A**) and chilling injury (**B**) of 'Honey Dew' melons as a function of their degree of exposure to total solar and UV radiation during their maturation (FE = fully exposed; transparent Tedlar film; S12, S60, D60 = one layer of 12-mesh, one layer of 60-mesh, or two layers of 60-mesh cheesecloth, respectively; DB = double bag). Only the curves for the total radiation have been fitted to the data; SY = 18.67 + 0.21SR + $0.048SR^2$, $r^2 = 0.969$, $P = 0.005$; CI = −2.30SR + 451, $r^2 = 0.774$; $P = 0.021$. U_1 and U_2, respectively, approximate the values if the reduction in UV exposure had a major influence on SY or CI development. (Vertical bars = SE; each mean is based on 33 to 41 melons used during 4 years)

ACC concentration. The ACC levels in the skin of top and bottom portions of melons from the three treatments tested (fully exposed, single layer of 60-mesh cheesecloth, double bags) were negligible and equal at harvest. The concentrations increased substantially in all treatments during 2½ weeks of subsequent chilling, but only about half as much in melons that had been fully exposed to solar radiation as in those that had been partially shaded (Table 2). Complete shading resulted in little additional increase in ACC. The top portion consistently contained slightly less ACC than the bottom portion, regardless of degree of preharvest exposure of the melons to solar radiation.

Table 2. Influence of preharvest solar exposure on ACC accumulation in 'Honey Dew' melons during their postharvest chilling.

Time of analysis	Location	ACC content (nmol·g^{-1} ± SE)[z] Degree of exposure (%)[y] 100	54	1
At harvest	Top	0.4 ± 0.07	0.3 ± 0.05	0.3 ± 0.06
	Bottom	0.4 ± 0.07	0.4 ± 0.06	0.3 ± 0.05
After chilling[x]	Top	12 ± 1.9	22 ± 2.3	26 ± 2.6
	Bottom	15 ± 2.3	26 ± 3.0	29 ± 3.3

[z]n = 14 or 15 melons; SE = standard error of mean.
[y]Treatments: Fully exposed, covered with one layer of 60-mesh cheesecloth, or double bagged, respectively.
[x]Seventeen days at 2.5°C.

Discussion

The overwhelming occurrence of SY on or near the top of 'Honey Dew' melons leads to the conclusion that direct exposure to solar radiation is principally responsible for the development of SY. The small amount that developed in the lower portion of the melons may have been induced by reflected radiation, as from the soil surface. The presence of slight SY in the bagged melons suggests that very low levels of solar radiation are sufficient for development of SY, or that there was a slight carry-over effect from before the melons were bagged. We favor the latter explanation. Temperature appears to have had no influence on SY development; the maximum temperatures for melons covered with two layers of 60-mesh cheesecloth or double bags were nearly or actually identical (38° and 36°C, respectively, when the outer bags were white; 41° for both when they were brown), but their severity factors for SY (105 and 2, respectively) differed substantially.

The influence of solar radiation on development of CI was negative and less dramatic than on SY. The lesser influence of solar radiation on CI would be expected, because CI was strictly a postharvest disorder in these melons and, therefore, could not have been a direct response to exposure. In contrast to 'Honey Dew' melons, the sun-exposed side of grapefruit was more susceptible to CI than the shaded side (11). Purvis (12) attributed much of the difference to greater water loss from the exposed side. We have no analogous data for the melons to decide whether the difference in CI development between top and bottom is related to differences in water loss.

Out data imply that exposure to UV radiation has a minimal, if any, effect on SY or CI. If the 80% reduction in UV exposure by Tedlar had exerted a major influence on development of SY, the severity factor for these melons should have been about 80 (Fig. 1A, location U_1) rather than nearly 300. This high value reflects the response of the melons to the high transparency of Tedlar to long-wave radiation (>390 nm). Similarly, if the reduction in UV radiation under Tedlar would have had a major influence on CI, then the severity factor for Tedlar should have been about 400 (Fig. 1B, location U_2) rather than the actual 200. Conclusive results regarding the influence of UV radiation on SY or CI would require exposure of 'Honey Dew' melons to various doses of UV radiation of specific wavelengths and under carefully controlled conditions, rather than in the open.

The moderately strong, negative effect of SY on the susceptibility of 'Honey Dew' melons to CI (Fig. 2) complements the observation that CI developed primarily in the lower, partially, or completely shaded portion of the melons.

These and previous experiments (9) demonstrate that degree of preharvest exposure to solar radiation influences postharvest responses related to CI, as exemplified by the relationship between SY and the accumulation of ACC during chilling. The two variables were linearly and inversely related for the top (r^2 = 0.999; ACC = −0.0259SF for SY + 25.98; P = 0.007) and bottom (r^2 = 0.996; ACC = −0.0265SF for SY + 29.44; P = 0.04) skin portions. The nearly equal slopes suggest that the influence of solar radiation extends to the entire surface of the melon and not just to the portion directly exposed. The slightly (15%), but consistently, lower ACC levels in the top than in the bottom portion suggest, however, that the potential for ACC formation in the skin depends not only on the degree of exposure to solar radiation, but also on endogenous differences between top and bottom. The higher ratio of unsaturated to saturated membrane fatty acids in the skin of exposed than of shaded melons (1) may account for the difference between top and bottom in ACC accumulation during chilling.

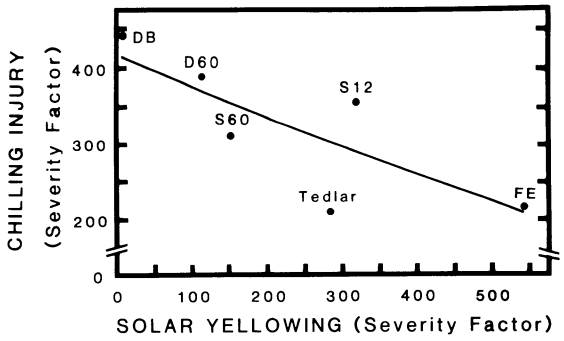

Fig. 2. Chilling injury of 'Honey Dew' melons as a function of solar yellowing (CI = −0.387SR + 413; r^2 = 0.617; P = 0.064). Data are means for 4 years.

Literature Cited

1. Forney, C.F. 1985. Membrane fatty acid composition of 'Honey Dew' melons as related to ripening, solar exposure, and chilling injury. HortScience 20:587. (Abstr.)
2. Howell, T.A., D.W. Meek, C.J. Phene, K.R. Davis, and R.L. McCormick. 1984. Automated weather data collection for research on irrigation scheduling. Trans. ASAE 27:386–391, 396.
3. Kader, A.A., W.J. Lipton, and L.L. Morris. 1973. Systems for scoring quality of harvested lettuce. HortScience 8:408–409.
4. Lipton, W.J. 1978. Chilling injury of 'Honey Dew' muskmelons: symptoms and relation to degree of ripeness at harvest. HortScience 13:45–46.
5. Lipton, W.J. 1984. Solar radiation influences development of solar yellowing and of chilling injury in 'Honey Dew' melons. HortScience 19:592. (Abstr.)
6. Lipton, W.J. and Y. Aharoni. 1979. Chilling injury and ripening of 'Honey Dew' muskmelons stored at 2.5° or 5°C after ethylene treatment at 20°C. J. Amer. Soc. Hort. Sci. 104:327–330.
7. Lipton, W.J. and J.J. O'Grady. 1980. Solar injury of 'Crenshaw' muskmelons: the influence of ultraviolet radiation and of high tissue temperatures. Agr. Met. 22:235–247.
8. Lipton, W.J. and B.E. Mackey. 1984. Ethylene and low-temperature treatments of honeydew melons to facilitate long-distance shipment. USDA ARS-10.
9. Lipton, W.J. and C.Y. Wang. 1987. Chilling exposures and ethylene treatment change the level of ACC in 'Honey Dew' melons. J. Amer. Soc. Hort. Sci. 112:109–112.
10. Pratt, H.K., J.D. Goeschl, and F.W. Martin. 1977. Fruit growth and development, ripening, and the role of ethylene in the 'Honey Dew' muskmelon. J. Amer. Soc. Hort. Sci. 102:203–210.
11. Purvis, A.C. 1980. Influence of canopy depth on susceptibility of 'Marsh' grapefruit to chilling injury. HortScience 15:731–733.
12. Purvis, A.C. 1984. Importance of water loss in the chilling injury of grapefruit stored at low temperature. Scientia Hort. 23:261–267.