Orchard Cooling with Overtree Sprinkler Irrigation to Improve Fruit Color of ‘Delicious’ Apples

I. Iglesias
Institut de Recerca i Tecnologia Agralimentaries (IRTA), Estació Experimental de Lleida Avda, Rovira Roure, 177, 25198-Lleida, Spain

J. Graell and G. Echeverría
Area de Postcollita, Centre UdL-IRTA, Avda, Rovira Roure, 177, 25198-Lleida, Spain

M. Vendrell
CSIC-Centro de Investigación y Desarrollo, Jordi Girona, 18-26, 08034-Barcelona, Spain

Additional index words. anthocyanin, quality, colorimeter, temperature

Abstract. The influence of supplemental sprinkler irrigation on fruit color of ‘Oregon Spur Delicious’ (Trumodor) apples (Malus × domestica Borkh.) was evaluated in the area of Lleida (NE Spain) over a 3-year period. Cooling irrigation was applied for 2 hours daily for 25–30 days preceding the harvest. Three treatments were evaluated: 1) control without overtree sprinkler irrigation; 2) sprinkler irrigation applied at midday; and 3) sprinkler irrigation applied at sunset. Fruit color was significantly affected by the cooling irrigation and also by the weather of the particular year. Increased red color and higher anthocyanin content resulted from sprinkler irrigation, especially when applied at sunset. At harvest, anthocyanin content was correlated with a*/b* and hue angle, suggesting that the colorimeter measurements could provide a nondestructive estimate of anthocyanin content.

Red color and fruit size are the primary grading standards for European Union countries. Even with adequate size, poor fruit color is an important cause for reduction in grade and is generally associated with poor consumer acceptance. One way to compensate for poor color is by developing new strains with high coloring potential, even in hot areas (Curry, 1997; Iglesias, 1990; Iglesias et al., 1999a). Overtree or microjet sprinkling has been used in the warmer areas of eastern Washington State for evaporative cooling to enhance color formation. Trials conducted with ‘Delicious’ strains showed that this technique significantly improved fruit color and size (Iglesias et al., 1999c; Recasens, 1982; Unrath, 1972a, b), especially in locations having high temperatures and low relative humidity.

Materials and Methods

Plant material, experimental design, sample collection. This study was conducted in 1992, 1993, and 1994 using ‘Oregon Spur Delicious’ apple trees on MM·106 rootstock in a commercial orchard (Lleida, NE Spain). The cooling schedule started in early August, 25–30 d before harvest. Water was applied daily, independent of orchard temperature, for 2 h at two different times. Treatments were: 1) control without sprinkler irrigation for cooling; 2) sprinkler irrigation applied at midday (1500–1700 h); and 3) sprinkler irrigation applied at sunset. Fruit color was significantly affected by the cooling irrigation and also by the weather of the particular year. Increased red color and higher anthocyanin content resulted from sprinkler irrigation, especially when applied at sunset. At harvest, anthocyanin content was correlated with a*/b* and hue angle, suggesting that the colorimeter measurements could provide a nondestructive estimate of anthocyanin content.

Effect of evaporative cooling on anthocyanin content. Mean anthocyanin content increased continuously on both sides of the fruit (data not shown) in the last 2 weeks before harvest. In late August and at harvest, anthocyanin content was significantly higher in fruit that were cooled at sunset than in the control, whereas cooling at midday was less effective. Anthocyanin content for ES was higher than for SS (Table 1). Both cooling treatments improved red pigmentation significantly, in accordance with results reported by several researchers with ‘Delicious’ strains using continuous or pulsed overtree sprinkler irrigation in warm regions (Iglesias et al., 1999c; Recasens, 1982; Unrath, 1972b). Phenylalanine ammonia-lyase (PAL) activity, and consequently the synthesis of anthocyanin, is also greater at lower temperatures (Faragher, 1983; Iglesias et al., 1999b; Tan, 1980).

Relationship between anthocyanin content and chromaticity values. Simple nonlinear models were used to relate anthocyanin content with chromaticity values. The $R^2$ values obtained with $a^*/b^*$ ratio (0.84) and hue (0.81) were best; that with $L^*$ (0.78) was intermediate. These results are similar to those reported by several researchers relating chromaticity values to anthocyanin content (Iglesias et al., 1999a; Singha et al., 1991).
Table 1. Main effects of cooling irrigation of ‘Oregon Spur Delicious’ apple during August and September on colormetric values and anthocyanin content.

| Treatment | L* Aug. | L* Sept. | a*/b* Aug. Sept. | hue (°) Aug. Sept. | Anthocyanin (nmol·cm⁻²) Aug. Sept. |
|-----------|---------|----------|------------------|--------------------|-----------------------------------|
| **1992**  |         |          |                  |                    |                                   |
| A. Timing  |         |          |                  |                    |                                   |
| Sunset    | 55.7 b  | 41.2     | 0.47 a 1.2 a     | 73.9 b 42.4 b      | 15.4 a 21.7 a                    |
| Midday    | 56.5 b  | 42.1     | 0.34 b 1.1 b     | 77.0 b 45.5 ab     | 13.2 b 19.1 ab                    |
| Control   | 57.9 a  | 41.0 a   | 0.16 c 0.9 c     | 83.9 a 50.0 a      | 12.1 b 17.4 b                     |
| B. Position on fruit |         |          |                  |                    |                                   |
| ES        | 51.9 b  | 36.7 b   | 0.74 a 1.5 a     | 63.9 b 34.1 b      | 20.2 a 27.3 a                     |
| SS        | 60.9 a  | 48.2 a   | -0.11 b 0.6 b    | 92.5 a 58.2 a      | 7.0 b 11.6 b                      |
| Interaction A × B | NS      | NS       | *                | NS NS              | NS NS                            |
| **1993**  |         |          |                  |                    |                                   |
| A. Timing  |         |          |                  |                    |                                   |
| Sunset    | 48.9    | 40.8 b   | all NS           | 17.6 a 39.3 a      |                                   |
| Midday    | 49.0    | 41.3 b   | all NS           | 13.3 b 33.4 b      |                                   |
| Control   | 51.0 a  | 48.1 a   | all NS           | 12.0 b 31.3 b      |                                   |
| B. Position on fruit |         |          |                  |                    |                                   |
| ES        | 41.1 b  | 36.5 b   | 1.8 a 2.6 a      | 31.0 b 21.5 b      | 22.8 a 52.2 a                     |
| SS        | 58.1 a  | 50.3 a   | 0.1 b 1.1 b      | 83.6 a 43.4 a      | 5.8 b 17.2 b                      |
| Interaction A × B | NS      | NS       | *                | NS NS              | NS NS                            |
| **1994**  |         |          |                  |                    |                                   |
| A. Timing  |         |          |                  |                    |                                   |
| Sunset    | 58.3 b  | 46.3 b   | 0.3 a 1.0 a      | 75.9 b 50.3 b      | 7.8 a 24.0 a                      |
| Midday    | 59.1 b  | 52.9 ab  | 0.2 b 0.6 b      | 79.5 b 59.3 a      | 6.6 ab 19.3 b                     |
| Control   | 60.4 a  | 55.3 a   | 0.2 b 0.5 b      | 84.5 a 64.1 a      | 5.7 b 17.7 b                      |
| B. Position on fruit |         |          |                  |                    |                                   |
| ES        | 54.2 b  | 45.3 b   | 0.5 a 1.2 a      | 64.6 b 38.6 b      | 9.8 a 30.1 a                      |
| SS        | 64.3 a  | 60.0 a   | -0.1 b 0.2 b     | 95.4 a 77.2 a      | 3.8 b 10.5 b                      |
| Interaction A × B | NS      | NS       | *                | NS NS              | NS NS                            |

zData recorded 25 Aug. in 1992 and 1993, 22 Aug. in 1994.
yData recorded 8 Sept. in 1992 and 1993, 5 Sept. in 1994.
xSunset: 2100 –2300 HR; Midday: 1500–1700 HR.
wMean separation within columns, chromaticity parameters, anthocyanin content and years by Duncan’s new multiple range test (P ≤ 0.05).

**NS, *,**, Nonsignificant or significant at P = 0.05 or 0.01, respectively.

**Literature Cited**

Chalmers, D.J., J.D. Faragher, and J.W. Raff. 1973. Changes in anthocyanin synthesis as an index of maturity in red apple varieties. J. Hortic. Sci. 72:723–729.

Faragher, J.D., 1983. Temperature regulation of anthocyanin accumulation in apple skin. J. Expt. Bot. 34:1291–1298.

Hunter, R.S. 1975. The measurement of appearance. Wiley, New York.

Iglesias, I. 1990. Colección de variedades del grupo ‘Red Delicious’ del campo experimental de frutales de Seana-Bellpuig (Lleida). Info. Téc. Econ. Agraria 85:45–56.

Iglesias, I., J. Gaella, G. Echeverría, and M. Vendrell. 1999a. Differences in fruit color development, anthocyanin content, yield, and quality of seven ‘Delicious’ apple strains. Fruit Var. J. 53:133–145.

Iglesias, I., J. Gaella, D. Faro, C. Larriaguie, I. Recasens, G. Echeverría, and M. Vendrell. 1999b. Efecto del sistema de riego en la coloración de los frutos, contenido de antocianos y actividad de la fenilalanina amonoliasa (PAL), en la variedad de manzana ‘Starking Delicious’. Invest. Agr.: Prod. Prot. Veg. 14:157–172.

Iglesias, I., J. Gaella, G. Echeverría, and M. Vendrell. 1999c. Efecto del riego refrescante por aspersión en la mejora del color y de la calidad en manzanas cv. ‘Topred Delicious’. Info. Téc. Econ. Agraria 95:267–288.

McGuire, R.G. 1992. Reporting of objective color measurements. HortScience 27:1254–1255.

Recasens, D.I. 1982. Estudio de diversos parámetros fisiológicos durante el crecimiento del fruto. Aplicación a la variedad ‘Starking Delicious’. PhD Diss., Barcelona Univ. Bellatera. (Abstr).

SAS Institute. 1997. SAS/STAT® user’s guide. Vers. 6.12. SAS Inst., Cary, N.C.

Singha, S., T.A. Baugher, E.C. Townsend, and M.C. D’Souza. 1991. Anthocyanin distribution in ‘Delicious’ apples and the relationship between anthocyanin concentration and chromaticity values. J. Amer. Soc. Hort. Sci. 116:497–499.

Tan, S.C. 1980. Phenylalanine ammonia-lyase and the phenylalanine ammonia-lyase inactivating system: Effects of light, temperature and mineral deficiencies. Aust. J. Plant Physiol. 7:159–167.

Unrath, C.R. 1972a. The evaporative cooling effects of overtree sprinkler irrigation on ‘Red Delicious’ apples. J. Amer. Soc. Hort. Sci. 97:55–58.

Unrath, C.R. 1972b. The quality of ‘Red Delicious’ apples as affected by overtree sprinkler irrigation. J. Amer. Soc. Hort. Sci. 97:58–61.