Evapotranspiration-based Irrigation Systems and Nitrogen Effects on Yield and Fruit Quality at Harvest in Fully Mature ‘Fuji’ Apple Trees over Four Years

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Abstract. In a long-term study between 2008 and 2011, the use of crop evapotranspiration (ETc), when a precise crop coefficient value (Ke) was used, provided a reliable irrigation scheduling for determination of water requirement for ‘Autumn Rose Fuji’ apple (Malus × domestica Borkh) fully mature trees. Water use, yield, and fruit quality attributes at harvest were examined under various irrigation and nitrogen (N) systems that were scheduled using ETc. Trees with a full sprinkler (FS) system received ≈39% to 41% more water than those with a full drip (FD) system during the period of 2008–11 growing seasons. On average, mature trees with an FS system received 5927.6 L (944 mm), whereas those with an FD system received 3610.3 L of water per tree (554.9 mm) per growing season over the period of 2008 through 2011. Fruit from trees with FS and FD were larger, whereas those with 50% FS were smaller than those from all other treatments. Trees with 50% FS treatment received a higher volume of water but had smaller fruit size than those with 50% FD or 65% FD. Averaging values over 4 years revealed that applications of any form of deficit irrigation (DI), either by microjet irrigation or drip, increased fruit soluble solids concentration (SSC) and firmness but decreased water core at harvest. Considering yield, and quality attributes in this study, a well-calculated ETc-based FD irrigation system is recommended over any other irrigation regime. If application of deficit water is mandated, application of 65% FD is preferred over 50% FS, as trees with 65% FD treatment received less water while had larger fruit than those of 50% FS. Trees receiving 80 g N/tree had lower fruit color and russet than those receiving 40 g N/tree. However, other yield and quality attributes were unaffected by the rate of N fertigation.

The decrease in irrigation water availability mandates a more efficient use of water in agriculture. Merging new orchard designs with more efficient irrigation systems can result in lower water consumption (Fallahi et al., 2007a, 2007b) while producing higher quality fruit (Behboudian and Mills, 1997; Behboudian et al., 2005; Fallahi et al., 2007a, 2007b; Naor, 2006). The method of irrigation and injection of nutrients, particularly nitrogen (N) through water, affects water consumption and fruit quality in apples which are critical issues in many parts of the world, including the Pacific northwest region of the North America (Fallahi et al., 2007a; Neilsen et al., 1994, 2009).

Leib et al. (2006) indicated that fruit size and yield of ‘Fuji’ apple in DI were similar to those of partial root zone drying irrigation and conventional irrigation (CI) in the semi-arid climate of Washington State. Naor et al. (2008) reported that yield and fruit size decreased as the rate of irrigation was reduced in ‘Golden Delicious’ apple in Israel. Previous reports indicate that a reduction in water application may result in reduction in apple firmness, relating this observation to the advanced maturity in fruit with water stress (Drake et al., 1981; Mills et al., 1994). However, other researchers have shown that apples from nonirrigated plots were firmer than those from irrigated plots (Assaf et al., 1975; Guelfat-Reich and Ben-Arie, 1979; Guelfat-Reich et al., 1974), perhaps because fruit from nontreated plots had smaller size (Assaf et al., 1975).

Irrigation with a drip system uses less water than sprinkler irrigation (Fallahi et al., 2007b; Proebsting, 1994). However, irrigation through microjet sprinkler systems can improve the establishment and maintenance of orchard floor vegetation. Microjet sprinklers also create a cooler environment in the orchards under fruit-growing conditions of Washington and Idaho (E. Fallahi, personal observation). Research has been conducted with orchard fertigation through drip systems in British Columbia (Neilsen et al., 2006; Yao et al., 2001) and Europe (Zydlik and Pacholak, 2001). Although there has been some progress in understanding micro-irrigation systems and N application (Chun et al., 2001; Fallahi et al., 2001a, 2001b; Neilsen and Neilsen, 2006; Neilsen et al., 2004, 2008), information on yield and fruit quality in new apple cultivars under various regimes of drip or microjet sprinkler irrigation systems in the Pacific Northwest is lacking. Thus, the objective of this long-term experiment was to study the effect of five irrigation treatments consisting of two microjet sprinkler and three drip systems, using an ETc-based water scheduling, and two levels of N (40 g N/tree and 80 g N/tree) on water, yield, and harvest-time fruit quality attributes in fully mature ‘Autumn Rose Fuji’ trees.

Materials and Methods

Orchard establishment and general cultural practices. The experimental orchard was established at the Parma Research and Extension Center, University of Idaho, in the spring and early summer 2002. ‘Autumn Rose Fuji’ trees on M.9 RN 29 (Nic 29) rootstock (Columbia Basin Nursery, Quincy, WA) were planted at 1.52 × 4.27 m spacing with an east–west row orientation. ‘Snow Drift’ crab apple on RN 29 rootstock (C & O Nursery, Wenatchee, WA) was planted in each row as a pollinator between every 10 ‘Autumn Rose Fuji’ trees. All trees were trained to a vertical axis system during the dormant season in early March each year. Tree leaders were maintained at ≈3.55 m in height. The experimental site was located at 43.7853°N and 116.9422°W and had a semi-arid climate with an annual precipitation of ≈297 mm on a sandy loam soil of pH 7.3.

In general, cultural practices other than irrigation were similar to those recommended for commercial orchards in the Pacific Northwest (Washington State University, 2017). Crested wheatgrass (Agropyron cristatum (L.) Gaertn.), a drought-tolerant grass, was planted as the orchard floor cover in all treatments. Trees in all treatments were blossom thinned at ≥80% bloom with 5% lime sulfur, followed by one or two applications of postbloom thinners. The first postbloom thinner was a mixture of carbaryl (44.1% by weight a.i.; Sevin XLR; 1-naphthyl N-methylcarbamate; Bayer Crop Science; Research Triangle Park, NC) and Ethephon (21.7% a.i.; Ethrel [2-chloroethyl] phosphonic acid; Bayer Crop Science) at a rate of 0.125% to 0.156% of formulation and was applied at petal fall. The second postbloom thinner (when applied, depending on the crop

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The guard rows were not used for any part of any possible over-spray from the sprinkler between every two experimental rows. These mental rows. A row of guard trees was used gation regimes on each of the five experi-
gation, once a year in late May. Phosphorous, calcium and micronutrients, par-
to each tree-planting hole, only once at the time

diameter was 2.1 m. In this treatment, liters of water applied per
tree= (ETc in mm/percent
drip efficiency factor) × 1.52 × 4.27 m
spacing × %GS. ETc and GS values for completely mature trees were used
during the period of this study.

4. Sixty-five percentage FD: This system was similar to the FD system, except
that the amount of water applied in this system was 65% of that applied to FD
during 2008–11. This amount was ap-
plied to both sides of the trees at each
application and frequency of applica-
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5. Fifty percentage FD: This system was similar to the FD system, except
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Calculation for water application. Irriga-
tion started in about mid-May and ended in
mid-October every year. Shortly before the
first irrigation of the year, soil moisture was
measured using AquaPro Sensors (Draner, CA)
and trees were watered to the soil
saturation point. After this general irrigation,
water requirements were calculated based on
ETc where ETc= ETr × Kc. In this equation, ETr (Penman-Monteith reference evap-
transpiration) (Allen et al., 1998) was calcu-
lated from the AgriMet Parma Weather
Station data and Kc was the crop coefficient.
Year each since 2002, the crop water use
coefficient was calculated as Kc = Kc base +
%M × (mature KC – Kc base). Percent canopy
mortality (%M) was a measurement of can-
opy size and was calculated as %M = 3.05 +
2.558 × (%GS) – 0.016 × (%GS)^2. Kc base
was the base coefficient, calculated as the percen-
t area between the rows that was
occupied by a cover crop. In our experiment,
space between rows was 4.27 m and the
herbicide strip extended 0.61 m on either side
of the row. Thus, Kc base was [4.27 − (0.61 ×
2)]/4.27 = 0.71%. Percentage of GS was
estimated as the area of orchard shaded by
the tree canopy at different stages of growth.
Ground shading reached 62% and tree matura-
rity reached 100% in early Aug. 2005. Thus,
Kc values for mature trees were used during
the course of this experiment (2008–11),

1. Full sprinkler: A 30-cm microjet
sprinkler (Olson Ultra-jet, Santee, CA) was
connected to the lateral poly-
ethylene line. Each microjet sprinkler
was installed midway between two
adjacent trees and covered a complete
circle with a radius of 2.1 m. In
this treatment, the trees were irrigated
once a week at the full rate of evapotrans-
piration (ETc) for apple starting in
2002. During the period of this study
(2008–11), ETc values for fully mature
trees were used. Method for ETc cal-
culation is described in the “Calcula-
tion for water application” section.

2. Fifty percentage FS: This system was
identical to the FS system (as described
earlier), except that trees received only
50% of the volume that were applied to
the trees with FS once a week, starting
in 2002.

3. Full drip: One 16-mm drip line (Rain
Bird Corporation, Azusa, CA) was in-
stalled in a 10-cm trench (subsurface),
30 cm away from and parallel to the
tree row on each of the north and south
d sides of the tree row. Each of these lines
was connected to a pressure regulator
to keep the water pressure constant at
1.41 kg.cm^-2. Pressure compensating
emitters were spaced at 45 cm on each
line and each emitter delivered 2.27
L.h^-1 of water. Pressure compensation
ensured consistent flow from each
liner emitter throughout the entire
length of tubing and the emitter design
prevented debris from clogging emi-
ters for maximum performance. The
drip line on the north side of the tree
was “off-centered” with the line on the
south side to have better water cover-
age. Trees in this system were irrigated
twice a week at 100% of daily ETc (as
described later), but adjusted for the
ground shading area (GS). Therefore,
in this treatment, liters of water
applied per tree= (ETc in mm/percent
drip efficiency factor) × 1.52 × 4.27 m
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d sides of the tree row. Each of these lines
was connected to a pressure regulator
to keep the water pressure constant at
1.41 kg.cm^-2. Pressure compensating
overall years from 2008 through 2011 are reported in this report.

Water application

As expected, trees used the most water in July and August in all years. On average, trees with an FS system received ≈39% to 41% more water than those with an FD system over the period of 2008–11 (Table 1). Averaging values over the four seasons showed that mature trees with an FS system received 952.6 L of water per tree (944 mm) whereas those with an FD system received 3610.3 L of water per tree (554.9 mm) per season (Table 1). Each tree with 50% FS received more water than those of 65% FD and 50% FD systems (Table 1).

Trees receiving less than full levels of either sprinkler or drip irrigations had smaller tree canopies and slightly earlier leaf senescence in late October, perhaps because of increased stress in the trees with lower irrigation.

Leib et al. (2006) compared three microsprinkler irrigation systems in mature ‘Fuji’ trees in Washington State. In that study, the soil water content in the CI was maintained close to field capacity, which was only 60% to 70% of estimated ETc for apple without cover crop. They estimated that irrigation scheduling based on soil water measurements required 26% less water than what was predicted by the ETc model for an apple orchard without a cover crop. In that study, they applied a 3-year average of 707 mm of water whereas we applied an average of 944 mm over 4 years (≈25% more). This difference is perhaps largely due to the higher ETr and ETc values in Idaho than Washington. The difference could also be in part because trees receiving FS were applied with water at full ETc level in our study whereas the CI-treated trees in their experiment received water at ≈70% of ETc. Rainfall in both experiments was somewhat comparable.

Effects of irrigation treatments on yield and fruit quality attributes

Fruit yield. Yield in all treatment were higher, leading to smaller fruit size when the trees were fully mature in 2008–11 as compared with the period of 2004–07, when trees were younger (data not shown). Trees with FS and FD systems tended to have higher yield per tree than trees with other systems in 3 years (2009, 2010, and 2011), and differences were sometimes significant (Table 2). When those trees were younger, trees with DI were more precocious and had higher yield in the early years of their production because of the induction of water stress and more spur formation (data not shown).

Because trees with an FD system received less water than those with an FS system (Table 1) and had higher yield per tree than those with 50% FS, 65% FD, and 50% FD (Table 2), we suggest that FD is a preferred method of irrigation over other systems for ‘Fuji’ apples as far as yield and water consumption factors are considered. Trees with FS and FD irrigation always had higher TCA and more new shoots and foliage (data not shown) than those with other treatments in 2008–11.

Leib et al. (2006) reported that yield of ‘Fuji’ apple in DI and partial zone systems were similar to that of CI (Leib et al., 2006), perhaps because the irrigation volume applied in their CI trees was only 60% to 70% of estimated ETc, but ours was not. However, our results are in agreement with Naor et al. (2008) who reported that yield and fruit size decreased as the rate of irrigation was reduced in ‘Golden Delicious’ apple in Israel.

Fruit color. Fruit color was not consistently affected by irrigation treatment (Table 2). However, averaging values over 2008–11 period revealed that fruit from trees receiving 50% FS treatment had slightly better (more uniform red) color than those from most other irrigation treatments, perhaps because of the presence of a less dense canopy (smaller TCA) in the 50% FS-treated tree and thus better light penetration, as reported by Lancaster (1992). Mills et al. (1994) reported that DI increased skin red color in ‘Braeburn’ apple. In contrast, DI did not affect fruit color in ‘Pink Lady’ in Australia (O’Connell and Goodwin, 2007; Talluto et al., 2008). Table 1. Effects of different irrigation systems on total water application per season in millimeter (mm) and liter per tree (L/tree) during growing seasons of 2008–11.

|   | 2008 | 2009 | 2010 | 2011 | Avg 2008–11 | 2008 | 2009 | 2010 | 2011 | Avg 2008–11 |
|---|------|------|------|------|-------------|------|------|------|------|-------------|
| Irrigation |     |      |      |      |             |      |      |      |      |             |
| FS | 997.0 | 917.4 | 933.2 | 928.4 | 944.0 | 6,480.7 | 5,679.8 | 5,796.3 | 5,753.8 | 5,927.7 |
| 50% FS | 530.4 | 490.5 | 491.0 | 480.1 | 498.0 | 3,446.8 | 3,046.2 | 3,057.9 | 2,981.4 | 3,133.1 |
| FD | 583.7 | 536.7 | 547.4 | 531.9 | 559.4 | 3,798.2 | 3,490.7 | 3,561.8 | 3,590.5 | 3,610.3 |
| 65% FD | 393.2 | 360.7 | 366.5 | 375.4 | 374.0 | 2,556.8 | 2,346.6 | 2,385.5 | 2,443.2 | 2,433.0 |
| 50% FD | 311.4 | 286.5 | 289.1 | 294.8 | 295.5 | 2,026.3 | 1,863.7 | 1,880.5 | 1,918.1 | 1,922.3 |

1Irrigation applied to the trees: FS = full sprinklers (microjet, applied at 100% ETc); 50% FS = 50% of FS; FD = full drip, applied at 100% ETc, adjusted for ground shading; 65% FD = 65% of FD; 50% FD = 50% of FD.

2Fruit skin color rating: scale of 1 to 5, with 1 = 20% red, progressively to 5 = 100% red.

3Irrigation applied to the trees: FS = full sprinklers (microjet, applied at 100% ETc); 50% FS = 50% of FS; FD = full drip, applied at 100% ETc, adjusted for ground shading; 65% FD = 65% of FD; 50% FD = 50% of FD.

4Mean separation within columns by least significant difference at 5% level. Each value within each year represents the average of five blocks, each with 10 trees.

Table 2. Effects of different irrigation regimes on tree yield per tree, fruit weight, and color of ‘Autumn Rose Fuji’ at harvest in 2008–11.

| Yield (kg/tree) | Wt (g/fruit) | Color (Scale of 1 to 5) |
|----------------|-------------|------------------------|
| Irrigation | Avg 2008–11 | Avg 2008–11 | Avg 2008–11 |
| FS | 17.2 ab | 34.0 a | 29.5 a | 57.4 ab | 34.5 a | 277.1 a | 262.9 a | 271.1 a | 239.8 a | 262.4 a | 3.2 c | 3.7 a | 3.4 c | 3.5 a | 3.5 c |
| 50% FS | 19.4 a | 21.4 d | 15.0 b | 42.1 b | 23.5 b | 199.3 c | 172.6 c | 197.7 d | 166.3 b | 184.4 c | 3.9 a | 3.7 a | 4.1 a | 3.5 a | 3.8 a |
| FD | 18.5 ab | 29.3 ab | 17.9 b | 71.8 a | 34.4 a | 275.9 a | 269.0 a | 246.7 b | 230.4 a | 255.5 a | 3.7 ab | 3.8 a | 3.7 bc | 3.7 a | 3.7 ab |
| 65% FD | 12.3 b | 27.6 bc | 7.1 c | 53.8 ab | 27.5 b | 243.9 c | 209.2 b | 225.4 c | 179.2 b | 208.7 b | 3.5 bc | 3.7 a | 4.0 ab | 3.0 b | 3.5 bc |
| 50% FD | 17.8 ab | 22.9 cd | 15.0 b | 42.9 b | 24.7 b | 232.3 b | 213.1 b | 209.1 c | 177.0 b | 207.3 b | 3.2 c | 3.9 a | 3.7 bc | 3.4 a | 3.6 abc |
contradictory impacts of DI on fruit color could be due to differences between methods of water delivery (drip vs. sprinkler), cultivars, prevailing temperatures at harvest for different places, and/or volume of applied water in different DI studies.

**Fruit SSC.** Fruit from trees with 50% FS had significantly higher SSC in 3 of 4 years (Table 3), perhaps because of the smaller fruit size (Table 2). Averaging values over 4 years of 2008–11 showed that trees with FS and FD systems had significantly lower SSC (Table 3). Our results are in agreement with some of the previous researchers who reported that DI increased SSC, including sucrose, glucose, fructose, and sorbitol in apple fruit, perhaps because of an increase in the concentration of dry matter (Kilili et al., 1996; Mills et al., 1994; Mpelasoka et al., 2000, 2001; Naor, 2006). Leib et al. (2006) showed that SSC in fruit from trees receiving DI was higher than in fruit from trees receiving CI. A 2-year study by O’Connell and Goodwin (2007) on ‘Pink Lady’ in Victoria, Australia, showed that SSC tended to be higher in trees with DI than those with full irrigation in both years. In contrast, Talluto et al. (2008) reported that ‘Pink Lady’ fruit after deficit and full irrigation had similar SSC. Differences in the volume of water applied in DI treatments and method of calculation for water requirement (ETc vs. soil moisture content) could partially explain the contradictory results from different researchers.

**SDP.** Averaging over 4 years revealed that fruit from trees receiving 65% FD and 50% FD treatments had significantly higher SDP than those from other irrigation regimes (Table 3). Factors that lead to a greater hydrolysis of fruit starch can result in higher SSC in apples (Kramer, 1983). However, a simple fruit dip in iodine solution (SDP) may not always be a reliable measure of the sugar concentration of fruit. For example, in our study in 2009, fruit from trees receiving 50% FS treatment had a significantly higher SSC than those from FS irrigation regime whereas fruit in both treatments had a similar level of SDP (Table 3). This could be due to conversion of simple sugar to other metabolites.

**Fruit firmness.** Trees receiving FS and FD treatment had lower firmness than those receiving DI (50% FS, 65% FD, and 50% FD) every year and differences were often significant (Table 3). Likewise, other researchers showed that apples from nonirrigated plots were firmer than those from irrigated plots (Assaf et al., 1975; Guelfat-Reich and Ben-Arie, 1979; Guelfat-Reich et al., 1974). Assaf et al. (1975) indicated that fruit from trees subjected to water deficiency were smaller and firmer than those from conventionally irrigated trees. In contrast, some previous reports indicate that low water application may reduce apple firmness, because of the advanced maturity in fruit with water stress in ‘Golden Delicious’ (Drake et al., 1981) and ‘Braburn’ (Mills et al., 1994). Leib et al. (2006) observed that firmness of ‘Fuji’ apple was unaffected by DI treatments in five of six different measurements during 2001–03. Also, Talluto et al. (2008) showed that fruit firmness was unaffected by DI treatment in ‘Pink Lady’ apple. These observations suggest that the impact of DI on apple firmness may depend on the cultivar used in the study. Thus, a side-by-side study is required to reveal the potential cultivar-DI interactions.

**Fruit russet.** Averaging over the period of 2008–11, fruit from trees receiving FS and FD had significantly higher russet than those with other irrigation treatments (Table 4). A possible explanation is that trees receiving less water had smaller TCA and less dense foliage, so fruit do not get as much surface injury from the leaves during breezy or windy conditions, and thus have less russet. The lower fruit russet in these treatments may also have a physiological reason and this area deserves further investigation.

**Water core.** Trees receiving FS and FD treatments had higher percentages of water core than those receiving DI (50% FS, 65% FD, and 50% FD) every year and differences were often significant (Table 4). Marlow and Loecher (1984) and Mills et al. (1994) reported that a high concentration of sorbitol would lead to the development of water core.

**Fruit sunburn.** Trees with an FS system had lower sunburn incidence than those with DI treatments every year (Table 4). Trees from FS had larger canopies and TCA, and more foliage (data not shown) and thus protected the fruit against direct heat.

**Effects of nitrogen treatments on yield and fruit quality attributes.** Trees receiving 80 g N/tree had significantly lower fruit red color and russet than those receiving 40 g N/tree every year (Table 5). The lower fruit color in the trees receiving 80 g N/tree is perhaps due to to the presence of higher chlorophyll in the fruit tissue. None of the other yield or quality attributes was

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**Table 3. Effects of different irrigation regimes on soluble solids concentration (SSC), starch degradation pattern, and firmness of ‘Autumn Rose Fuji’ at harvest in 2008–11.**

| Irrigation | SSC (%Brix) | Average (2008–11) | SDP | Firmness (Newton) | Average (2008–11) |
|-----------|-------------|--------------------|-----|-------------------|-------------------|
| FS        | 15.40 bc    | 14.38 d            | 15.2 b | 13.95 b           | 15.52 b           |
| 50% FS    | 16.40 a     | 16.43 a            | 16.72 a | 14.99 a           | 16.12 a           |
| FD        | 15.06 c     | 14.85 d            | 15.88 b | 14.31 b           | 15.04 d           |
| 65% FD    | 15.81 b     | 15.36 c            | 16.60 a | 14.28 b           | 15.43 c           |
| 50% FD    | 15.58 b     | 15.98 b            | 15.98 b | 15.20 a           | 15.70 b           |

**Table 4. Effects of different irrigation regimes on fruit russet, water core, and sunburn in ‘Autumn Rose Fuji’ at harvest in 2008–11.**

| Irrigation | Russet (%) | Water core (%) | Sunburn (%) |
|-----------|------------|----------------|-------------|
| FS        | 11 a       | 18 a           | 18 a         |
| 50% FS    | 10 a       | 17 a           | 20 a         |
| FD        | 14 a       | 17 a           | 15 a         |
| 65% FD    | 12 a       | 19 a           | 19 a         |
| 50% FD    | 10 a       | 20 a           | 20 a         |

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[1]Irrigation applied to the trees: FS = full sprinklers (microjet, applied at 100% ETc); 50% FS = 50% of FS; FD = full drip, applied at 100% ETc, adjusted for ground shading; 65% FD = 65% of FD; 50% FD = 50% of FD.
[2]Mean separation within columns by least significant difference at 5% level. Each value within each year represents the average of five blocks, each with 10 trees.
significantly affected by the rate of N application (Table 5).

### Conclusion

A significantly greater volume of water is required for trees under full microjet sprinkler systems than those with drip systems. However, application of water through a drip system, calculated based on full ETC rate and adjusted for groundcover, can result in major water saving and often improve yield and fruit quality attributes. Application of 50% FS reduces yield and fruit weight whereas it may improve fruit color, SSC, and firmness. Fruit sunburn is reduced with application of water at full ETC rate in both sprinkler (FS) and drip (FD) systems because trees under these irrigation systems have a larger canopy and more foliage. Considering growth, yield, and fruit quality attributes in this study, a well-calculated ETC-based FD irrigation system is recommended over any other irrigation regime for modern high-density apple orchards. ‘Fuji’ apple trees can be maintained with drip irrigation at 65% of drip ETC rate (i.e., 65% FD) if certain fruit quality attributes, such as fruit weight, are not of major concern for production. Application of water through a drip system at 65% of FD ETC rate would be preferred over the 50% FD regime if better fruit size at a reduced irrigation level was desired.

With an increasing demand for new cultivars, higher orchard tree density, and different canopy architectures, the impact of various irrigation systems and rates of water application on fruit quality and yield of apples needs to be further studied. Also, a concerted effort by various researchers is required to conduct an extensive study with a uniform set of cultivars and uniform protocol of irrigation over a wide range of climates to reveal the potential interactions between DI and apple yield and quality.

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Table 5. Effects of deficit irrigation on fruit color and yield, and other quality attributes of ‘Autumn Rose Fuji’ at harvest in 2008–11.

| Nitrogen rate | Fruit color rating | Firmness | SSC (%) | Dry matter (%) | Water core (%) | Sunburn (%) | Bitter pit (%) |
|---------------|-------------------|----------|---------|----------------|----------------|-------------|---------------|
| 40 g/tree | 3.48 a | 3.02 a | 8.3 a | 3.2 a | 2.1 a | 0.5 a | 1.0 a |
| 35 g/tree | 3.57 a | 3.11 a | 8.5 a | 3.3 a | 2.2 a | 0.6 a | 1.1 a |
| 30 g/tree | 3.66 a | 3.20 a | 8.7 a | 3.4 a | 2.3 a | 0.7 a | 1.2 a |
| 25 g/tree | 3.74 a | 3.29 a | 8.9 a | 3.5 a | 2.4 a | 0.8 a | 1.3 a |

Note: The table shows the average over 2008–11 for each treatment. The fruit color rating is on a scale of 1 to 5, with 1 = 20% red, progressively to 5 = 100% red. Firmness is on a scale of 1 to 6, with 1 = lowest, progressively to 6 = highest.

**Fruit color rating (1–5):**
- 1: ≤20% red
- 2: 21–40% red
- 3: 41–60% red
- 4: 61–80% red
- 5: ≥81% red

**Firmness (Newton):**
- 1: ≤2.0 Newton
- 2: 2.1–3.0 Newton
- 3: 3.1–4.0 Newton
- 4: 4.1–5.0 Newton
- 5: ≥5.1 Newton

**SSC (Soluble solids concentration) subnet with 40 g/tree at harvest.**
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