Effect of Microsprinkler Irrigation on Pear Fruit Growth and Postharvest Quality

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Summary. A study was undertaken to determine if microsprinkler irrigation (MI) can provide sufficient water and produce similar yield and quality of pear (*Pyrus communis* L.) fruit as flood irrigation (FI) in a cracking (shrinking–swelling) clay soil. Soil water content and fruit quality attributes were measured under MI and FI in 2 years. Water potential of the upper 120 cm (47 inches) of soil was maintained at 0.1 to 0.3 MPa (14.5 to 43.5 lb/inch²) through most of the growing season in both MI and FI treatments. MI and FI treatments did not differ in their effect on fruit size, yield, or firmness decline during cold storage. No consistent effect on fruit susceptibility postharvest fungal decay related to irrigation treatment was observed. MI has the potential to reduce chemical and water movement to groundwater, while providing sufficient water to produce satisfactory yield and fruit quality in a cracking clay soil.

Irrigation is necessary for pear production in southern Oregon due to the Mediterranean climate with dry summers. Water defi-

cits can affect growth of pear fruit; larger fruit are produced by maintaining soil moisture availability throughout the growing season (Lewis et al., 1934; Mitchell, et al., 1984). Fruit dessert quality parameters, such as sugar content, flavor, and acidity increase and fruit juiciness decrease with increasing water deficit (Aldrich et al., 1940; Cabral et al., 1995).

Water stress can also affect fruit ripening and storage life. Firmness of pear fruit is usually used as an indicator of pear maturity or ripeness (Kingston, 1992). Pears from trees having the least water deficit near harvest time usually show a lower firmness during the harvest period (Aldrich et al., 1940). Internal breakdown in ripe pears harvested late in the season is more prevalent in fruit experiencing greater water deficits near harvest (Aldrich et al., 1940).

Soil physical properties affect water infiltration and availability to plants. In southern Oregon, most pear trees are grown on clay soils which have a high swelling and shrinking properties (Chen, 1998). Volume of this soil changes continuously with changing water content, which is observed in the field as the formation of shrinkage cracks with high saturated infiltration rates during the dry period and crack closure with low infiltration rates during the wet period. Irrigation method and timing are critical in such shrinking–swelling soil.

Impact sprinkler and flood irrigation are characterized by high application rates of short duration, separated by relatively long intervals without irrigation. During dry periods, when irrigation rate exceeds the infiltration rate of the soil matrix the excess free water may move along the shrinkage cracks and other macropores down to subsoil to form macropore flow (Beven and Germann, 1982). Irrigation method has been shown to greatly affect water and chemical movement through clay soil of this structure (Miller et al., 1965; Kosmas et al., 1991; Jaynes and Rice, 1993). Micro-irrigation systems, such as microsprinklers, can apply water sufficiently slowly to reduce or eliminate macropore flow (Wu, 1995; Selker et al., 1995; Chen, 1998). However, the ability of a microsprinkler irrigation system to apply sufficient water for pear growth in such a shrinking–swelling clay soil is still unknown.

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The objective of this study was to evaluate a microsprinkler irrigation system to determine if it could apply sufficient plant-available water to produce pears of sufficient size, number, and storage life for quality marketing, as compared to traditional flood irrigation. This work was part of a larger study examining water and chemical movement in cracking clay soils in an attempt to reduce surface and groundwater pollution potential by manipulating method of irrigation (Chen, 1998).

Materials and methods

EXPERIMENTAL SITE. The study was conducted at the Southern Oregon Research and Extension Center (SOREC) near Medford, Ore. The soil is classified as Carney clay (fine, montmorillonitic, mesic Typic Chromoxererts). This soil has a high shrinking–swelling characteristic. The soil is moderately well-drained, has very low permeability, and is underlain by a shallow groundwater table whose depth fluctuates seasonally from 1 to 4 m (3.3 to 13 ft). The experimental site has an elevation of about 400 m (1312 ft), and mean annual precipitation of 479 mm (18.9 inches), with about 76% normally occurring from October through March. Pear trees ('Bosc') were planted in 1935 on a 7.3 × 7.3 m (24 × 24 ft) spacing. Grass strips were maintained between tree rows.

IRRIGATION SYSTEMS. Two irrigation systems, microsprinkler irrigation (MI) and flood irrigation (FI), were installed in adjacent areas within the orchard. The MI system used Dan 8000 series sprinklers with round spinners and 1.4 mm (0.06 inches) nozzles, operating at 207 kPa (30 lb/inch²) pressure (Netafilm, New York, N.Y.). Each sprinkler applied water at a rate of 2.8 mm·h⁻¹ (0.11 inches/h) and wetted an area 3 m (9.8 ft) in diameter. Emitters were installed at a distance of 3.7 m (12 ft) from one another at a height of 0.25 m (0.8 ft). This gave little or no overlap of irrigation water. Digital irrigation timers were used to control the irrigation system. During the 1995 irrigation season, the MI system ran 12 h weekly in a single event, and operated 6 h twice per week in 1996. Irrigation treatments began late July in 1995, and in early June in 1996.

Flood irrigation followed conventional orchard practice. Irrigation pipe was placed perpendicularly to the tree rows, and two gate valves on the pipe

were opened between adjacent tree rows. Water flowed gravitationally from one end of the tree rows to the other. Rate of flow in each valve was 49.5 L·min⁻¹ (13.1 gal/min), equivalent to 100 mm·d⁻¹ (3.9 inches/d), assuming uniform application. Flood irrigation was applied once every 2–3 weeks. Total amount of water applied in each growing season was similar for the two systems.

SOIL WATER MEASUREMENT. Two neutron probe access tubes were installed in each irrigation plot in late August 1995. To increase the resolution of the measurement, two additional tubes were installed in each plot in 1996. Soil water content was measured every 1–2 weeks during summer, using a CPN 503 neutron moisture meter

(CPN company, Martinez, Calif.). To avoid interference between irrigation treatments, all soil water measurement locations were at least two tree rows

Fig. 1. Mean gravimetric soil water content at 0–20 cm (0–8 inches), 40–60 cm (16–24 inches), 90–120 cm (35–47 inches) for microsprinkler irrigation (MI) and flood irrigation (FI) treatments in 1995. The error bars with symbols at lower left corner of the graphs represent the average standard deviations for 0–20, 40–60, and 90–120 cm depths. Ranges of the standard deviation for 0–20, 40–60, and 90–120 cm are 0.002–0.003, 0.006–0.011, and 0.001–0.003 for MI, and 0.005–0.011, 0.005–0.011, and 0.015–0.022 for FI; 0.01 g·g⁻¹ = 1%.

inside of the irrigation treatment borders.

FRUIT SIZE, WEIGHT, AND YIELD MEASUREMENTS. Four trees were selected in each irrigation plot at least two tree rows from the irrigation treatment borders and 25 randomly selected fruit in each tree were labeled. Diameters of the labeled fruit were measured with a caliper every two weeks in the early stages of

growth and weekly in late stages. At harvest, the yield of each tree was obtained, and 100 pears (50 in 1995) were randomly selected to measure the average fruit weight.

FRUIT FIRMNESS AND FUNGAL DECAY DETERMINATIONS. Forty pears from each tree were used for firmness determinations. Ten were used to measure the firmness at harvest, and the other 30 were stored at 0 °C (32 °F). After 2, 3, and 4 months of storage, samples of 10 pears were withdrawn to test firmness, using a U.C. firmness tester fitted with a 7.6 mm (0.3 inches) tip (Western Ind. Supply, San Francisco, Calif.). Two sides of each of the ten fruit were tested, with the peel removed. Average of the 20 measurements was used as the firmness index.

Another 10 pears from each tree were wounded and inoculated with a suspension of *Penicillium expansum* Link, causal agent of blue mold of pear, containing 10,000 spores/mL. Five wounds [each 5 mm (0.2 inches) in

diameter] were made in each fruit with a sterile finishing nail. Each wound was inoculated with 40 mL the *Penicillium expansum* spore suspension. Inoculated fruit were stored at 0 °C for 2 months, then the diameters of resulting lesions were measured with a caliper. Average value of the five lesions on each fruit was obtained as the index of fungal decay. Decay measurements were performed in order to determine if irrigation treatment had an effect on fruit susceptibility to postharvest decay.

STATISTICAL ANALYSIS. Differences of pear diameter, yield, fruit weight at harvest, and lesion diameter at the end of storage period between irrigation treatments were analyzed by *t* test. Linear regression analysis was used to analyze the difference in the rates (slopes) of firmness decline. All the statistical analyses were performed at *P* = 0.05 probability level. Computer software STATGRAPHICS (Manugistics, Inc., Rockville, Md.) was used for all statistical analyses.

Results and discussion

SOIL WATER CONTENT. Mean gravimetric soil water content at 0–20 cm (0–8 inches) and 40–60 cm (16–24 inches), during the period from early September to early October 1995, was maintained in the range of 0.29 to 0.31 g·g⁻¹ (29 to 31%) (Fig. 1), that was equivalent to 0.1 to 0.3 MPa (14.5 to 43.5 lb/inch²; Chen, 1998). MI and FI treatments were similar. Mean soil water content at 90–120 cm (35–47 inches) depth was 0.26 to 0.27 g·g⁻¹ (26 to 27%) in FI treatment during the same period, equivalent to 0.5 MPa (72.5 lb/inch²) and was about 0.02 g·g⁻¹ (2%) lower than in MI treatment. Variance of soil water contents between neutron probe access tubes was greater for FI at 90–120 cm depth than that for MI at the same depth (Fig. 1).

In 1996, soil water content at 0–20 cm and 40–60 cm depth fluctuated with irrigation events (Fig. 2). Water content at 90–120 cm was relatively stable in MI treatment except on 30 July 1996 where there was a pulse caused by a thunderstorm which delivered 33 mm (1.3 inches) of water in a short period of time (Fig. 2). In FI treatment, however, there were more pulses in the water content curve at 90–120 cm depth related to the irrigation events, that indicated that more water penetrated down to 120 cm at each irrigation event in FI treatment. The water percolate and chemi-

Fig. 2. Mean gravimetric soil water content at 0–20 cm (0–8 inches), 40–60 cm (16–24 inches), 90–120 cm (35–47 inches) for microsprinkler irrigation (MI) and flood irrigation (FI) treatments in 1996. The error bars with symbols at lower left corner of the graphs represent the average standard deviations for 0–20, 40–60, and 90–120 cm depths. Ranges of the standard deviation for 0–20, 40–60, and 90–120 cm are 0.003–0.032, 0.005–0.027, and 0.000–0.019 for MI, and 0.003–0.015, 0.003–0.016, and 0.013–0.045 for FI; 0.01 g·g⁻¹ = 1%.

Fig. 3. Cumulative fruit diameter and daily fruit diameter expansion rate for microsprinkler irrigation (MI) and flood irrigation (FI) treatments in 1995. The error bars represent ± 1 standard deviation; 25.4 mm = 1.0 inch.

Fig. 4. Cumulative fruit diameter and daily fruit diameter expansion rate for microsprinkler irrigation (MI) and flood irrigation (FI) treatments in 1996. The error bars represent ± 1 standard deviation; 25.4 mm = 1.0 inch.

cal collected at 120 cm depth was 100 times greater in FI than in MI treatment (Chen, 1998). Water contents at 0–20 cm and 20–40 cm depths were similar in MI and FI (Fig. 2). Mean water content was maintained at 0.29 to 0.32 g·g⁻¹ (29 to 32%) most of time except in mid-June where water con-

tent dropped to 0.26 g·g⁻¹ at 0–20 cm before irrigation was initiated. Larger pulses were found at each irrigation event of FI, reflecting the characteristics of high application rate and relatively long dry periods between irrigation events. Gravimetric water content of 0.29 to 0.32 g·g⁻¹ was equivalent to 0.1

to 0.3 MPa (14.5 to 43.5 lb/inch²; Chen, 1998), thus there was no shortage of available water during the growing season in either irrigation treatment.

FRUIT SIZE, WEIGHT, AND YIELD. Cumulative fruit diameter and daily diameter expansion rates were similar in MI and FI treatments during the growing season in 1995 and 1996 (Fig. 3 and 4). There was no difference between treatments (Figs. 3 and 4), and fruit diameter was not different between MI and FI at harvest (Tables 1 and 2).

Fruit weight and yield were not different between MI and FI treatments in both years (Tables 1 and 2). Mean fruit diameter and fruit weight at harvest were similar in 1995 and 1996. However, the mean yield in 1996 was about twice as high as in 1995.

FRUIT FIRMNESS AND FUNGAL DECAY. Pear fruit firmness decreased during storage (Figs. 5 and 6). Rate of firmness decrease (slope) was not different between the MI and FI treatments in both 1995 and 1996. The regression equation of firmness versus storage time was $Y = 65.23 - 1.90X$, with $R^2 = 0.61$ for MI, and $Y = 66.97 - 2.40X$, with $R^2 = 0.68$ for FI in 1995; and $Y = 61.14 - 1.62X$, with $R^2 = 0.22$ for MI, and $Y = 57.29 - 1.20X$, with $R^2 = 0.41$ for FI in 1996.

Diameter of the infected lesions of pear fruit after storage for two months was larger for fruit from MI than from FI in 1995, but was not different between the irrigation treatments in 1996. A consistent relationship between irrigation treatment and fruit decay susceptibility was not observed. Sugar et al. (1992) reported that low nitrogen and high calcium concentrations in pear fruit were important reduced susceptibility to fungal decay, and Raese and Stahly (1985) reported that dry treatment of 'Anjou' pear fruit had lower N/Ca ratios than normal or wet treatment fruit. Since water availability did not differ between irrigation treatments in the present study, it follows that these decay susceptibility factors were probably unaffected.

Conclusions

In this study, microsprinkler irrigation provided sufficient water for pear growth, as water potential of upper 120 cm soil was maintained at 0.1 to 0.3 MPa (14.5 to 43.5 lb/inch²) throughout the growing season. MI and FI irrigation treatments did not differ in their effect on fruit size, yield,

Table 1. Fruit size, weight, and yield at harvest and fungal decay lesion diameter after 2-month storage at 0 °C (32 °F) for microsprinkler irrigation (MI) and flood irrigation (FI) treatments in 1995 (25.4 mm = 1.0 inch; 28.4 g = 1.0 oz; 1.0 kg.m⁻² = 0.2 lb/ft²).

Treatment	Fruit diam (mm)	Fruit wt (g/fruit)	Yield (kg.m ⁻² trunk)	Lesion diam (mm)
MI	61.9 ^{NS}	160.0 ^{NS}	580 ^{NS}	17.9*
FI	62.9	168.5	600	14.6

*Nonsignificant or significant different between treatments using *t* test at *P* = 0.05 probability level.

Table 2. Fruit size, weight, and yield at harvest and fungal decay lesion diameter after 2-month storage at 0 °C (32 °F) for microsprinkler irrigation (MI) and flood irrigation (FI) treatments in 1996 (25.4 mm = 1.0 inch; 28.4 g = 1.0 oz; 1.0 kg.m⁻² = 0.2 lb/ft²).

Treatment	Fruit diam (mm)	Fruit wt (g/fruit)	Yield (kg.m ⁻² trunk)	Lesion diam (mm)
MI	61.3 ^{NS}	159.7 ^{NS}	1080 ^{NS}	20.0 ^{NS}
FI	64.3	187.0	1220	19.9

*Nonsignificant or significant different between treatments using *t* test at *P* = 0.05 probability level.

Fig. 5. Firmness of pear fruit during storage at 0 °C (32 °F) for microsprinkler irrigation (MI) and flood irrigation (FI) treatments in 1995.

and firmness decline. There was no consistent difference in postharvest fungal decay susceptibility related to irrigation treatment. With increasing concern about contamination of groundwater with agricultural chemicals, selection of an irrigation system with both environmental and agronomic value is critical. Microsprinkler system has the potential of reducing chemical and water loading to deep soil layers and groundwater, while sustaining satisfactory yield and fruit quality in a cracking clay soil.

Fig. 6. Firmness of pear fruit during storage at 0°C (32 °F) for microsprinkler irrigation (MI) and flood irrigation (FI) treatments in 1996.

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