Title: Water Use, Fruit Quality, Tree Growth and Development, and Nutritional Physiology as Influenced by Irrigation Systems in ‘Fuji’ and ‘Gala’ Apples and by Rootstock in ‘Gala’

Principal Investigator: Dr. Esmaeil "Essie" Fallahi, Professor and Tree Fruit Physiologist

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Cooperators: Dr. Jim McFerson, WTFRC
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Objectives: The primary hypothesis of this research is that apple tree performance, fruit quality, and yield are affected by method of irrigation and by rootstocks. Therefore, in this comprehensive project, we have three main objectives as follows:
1. To investigate the effects of five irrigation systems, including partial root-zone drying drip and sprinkler systems on fruit quality (fruit color, soluble solids concentrations, starch index, fruit size, ethylene and respiration), tree growth and development, precocity, yield, and mineral partitioning in ‘Autumn Rose Fuji’.
2. To study the influence of two irrigation systems on tree growth, yield, precocity, fruit quality, and mineral partitioning in ‘Desert Rose Fuji’.
3. To study tree growth, yield, precocity, fruit quality, and nutrition of 'Pacific Gala' apple as influenced by drip and sprinkler irrigation systems, with five rootstocks, Bud 9, M.9 RN 29, Supporter 4, G 30, and Bud 118.

Results and Significant Findings:
1) Water use was highest in late July 2002 and during entire July 2003 (Figures 1, 7, and 8).

2) Water usage per tree was higher in 2003 than 2002 (Figure 1 and 8).

3) Trees with full sprinkler and partial zone sprinkler received significantly greater water than those with drip systems in both 2002 and 2003 (Figures 1 and 8).

4) Size of ‘Desert Rose Fuji’ trees with double drip irrigation was not noticeably larger than those with single drip system in 2002 or 2003 (figure not shown). The differences may become significant in the future and should be studied further. Total leaf value for double drip was 2.19% dwt while that of single drip was 2.16% dwt (not a major difference) in 2003 (data not shown).

5) Trees with full sprinkler system received about 28 inches while those with partial zone drip received less than 5 inches of water during the entire 2003 growing season with minor or no visible damage to the trees with partial zone drip system (Figure 4).

6) At the peak of the water use (July), each full sprinkler tree received an average of 14 gal water per day while each tree with full drip system (either buried or above ground) received an average of 4 gal/tree in 2003 (Figure 8).

7) Trees with sprinkler irrigation had greater leaf N than those on other treatments in 2003 (Figure 6).

8) Trees with partial zone drying drip irrigation were smaller than other treatments. Tree size differences in other treatments were not large in 2003 (Figure 11).

9) Trees on Supporter 4 were larger followed by those on BUD 118, G30, RN29, and Bud 9 (Figure 12).

10) Following soil moisture may provide a useful guide but was not very exact indicative of water needs. ET r, ET c, with precise K c (crop coefficient) and precise estimate of tree canopy size are very important in determination of water needs. Both TDR and Aqua Pro were used to measure soil moisture. Aqua Pro sensors and access tubes were used at different depth in several replications for each irrigation treatment, and moisture status before and after each irrigation cycle were measured. Regression equations were developed and field capacity, bulk density, soil texture, and water holding capacity and several other soil physical and chemical parameters were determined. Water deficit
in each treatment was then determined and compared with values determined with ET c and ET a. The results will be discussed at the meeting.

Figure 1: Applied Water (gal/tree/Day) in ‘Autumn Rose’ Fuji in 2002

Figure 2: Applied Water (gal/tree) in Single vs. Double Drip in ‘Desert Rose’ Fuji, 2002

Figure 3: Applied Water to Pacific Gala in 2002
Figure 4: Total Water Applied to ‘Autumn Rose Fuji’ in Inches During 2003

Figure 5: Total Water Applied Per Tree to ‘Autumn Rose Fuji’ in Gallons During 2003

Figure 6: Leaf Nitrogen in ‘Autumn Rose Fuji’ with Different Irrigation Regimes, in 2003
Figure 7: Monthly Evapotranspiration, Crop Use, and Water Application in Fuji, 2003

Figure 8: Gallons of Daily Water Applied per Tree in 'Autumn Rose Fuji' During 2003.
Figure 9: Cumulative Evapotranspiration, Crop Use, and Water Application in Fuji, 2003

Figure 10: Tree Diameter (mm) in ‘Autumn Rose Fuji’ with Different Irrigation Regimes in November 2002
Figure 11: Tree Diameter (mm) in ‘Autumn Rose Fuji’ with Different Irrigation Regimes in November 2003

Figure 12: Tree Diameter (mm) in ‘Pacific Gala’ on Different Rootstocks,
Methods:

Irrigation Techniques for ‘Autumn Rose Fuji’ Apple (Objective 1):
The experimental orchard was established at the University of Idaho Pomology Orchards, at the Parma Research and Extension Center during spring and summer of 2002. ‘Autumn Rose Fuji’ trees on RN 29 (NIC 9) rootstocks were planted at 1.52 x 4.27 m (5 x 14 ft) spacing. The experimental design is a randomized complete block design, with five methods of drip or sprinkler irrigation systems with five blocks of 10-tree plots per irrigation treatment. Irrigation systems will be as follows:

1. Under Ground Full-Drip: In this system, one drip line is buried at 3-inch (7.5 cm) deep, 1 ft away from the tree row at each of the north and south sides of the tree row. An additional line may be installed at one ft away from the existing line on each side as trees grow. Each of these lines is connected to a pressure regulator to keep the water pressure constant at 20 PSI. Emitters are located at 0.45 m (1.5 ft) spacing on each line and each emitter delivers 0.6 gal water per hour. The drip line on the north side of the tree is “off-center” with the line in the south side to have a better water coverage.

2. Under Ground Deficit -Drip: With the exception of the amount of water application, this system is identical to treatment 1. Trees in this treatment will receive about 75% of the full drip irrigation.

   The drip lines were on the top of the ground during 2002 and 2003 seasons and amount of irrigation during these two seasons was same as that of full underground irrigation (treatment 1). However, from 2004 on, trees of this treatment will receive 75% of the treatment 1 irrigation.

3. Under Ground Alternate-Drip (Partial Root Zone Drying Using Drip): With exception to the frequency of irrigation, this system will be identical to treatment 1. At each irrigation cycle, trees are only irrigated by one of these drip lines and in the next cycle they will be watered by the other line (the number of irrigations on each side before switching to the other side of the tree row will be determined during 2004 growing season). During 2002 and 2003 seasons, the drip lines were on the surface (above ground) and each side was watered every other week; however, this can be adjusted). This way, a partial-root drying will be created to the trees. Partial root drying in wine grapes improves wine quality, but its impact on tree fruits is unknown.

4. Full-Sprinklers: In this system, a 30-cm (1 ft) micro-sprinkler (Olson Ultra-jet) is connected to the lateral polyethylene line. These micro-jet sprinklers are installed mid-way between the two adjacent trees. Each replication of the full-sprinkler treatment is regulated at 15 PSI with Rain Bird regulators (low flow to provide uniform water delivery) in each row and each sprinkler head covers a diameter of approximately 4.11 m (13.97 ft). This treatment is considered as the “Control” irrigation and will be watered at the rate of ET c. This was watered at ET c and some times at ET a rates (as described in water calculation later in this report) during 2002 and 2003. ET c = ET r x Kc. Kc is crop coefficient and is determined based on canopy growth and “base Kc” (described later).

5. Alternate-Sprinklers (Partial Root Zone Drying, Using Sprinklers): This system is similar to the full-sprinkler except that two 30-cm (1 ft) micro-sprinklers are fastened to two lateral polyethylene lines, each located either on the south (180°) or north side (180°) of the tree row. At each irrigation cycle, trees are irrigated only with sprinklers on one side and in the next cycle, they will be watered by sprinklers on the other line (the number of irrigations on each side before switching to the other side of the tree row will be determined during 2004 growing season; during 2002 and 2003 seasons, each side was watered every other week; however, this can be adjusted). At each irrigation time, trees in this treatment receive 50% of the “Full-Sprinkler” treatment (this percentage can also be easily adjusted). This way, only half of the tree root zones will irrigated at different times. Each replication and each side of the alternate-sprinkler treatment is regulated at 15 PSI regulators, and each sprinkler head covers a diameter of approximately 4.11 m (13.97 diameter or 6.99 ft radius).

Irrigation Techniques for ‘Desert Rose Fuji’ Apple (Objective 2):
The experimental orchard was established at the University of Idaho Pomology Orchards, at the Parma Research and Extension Center during spring and summer of 2002. ‘Desert Rose Fuji’ trees on RN 29 (NIC 9) rootstock were planted at 1.52 x 4.27 m (5 x 14 ft) spacing in spring of 2002. The experimental design is a randomized complete block design, with five 25-tree blocks per treatment. Two methods of drip irrigation (two treatments) are used in this study as follows:

1. Under Ground Double-Line Drip: In this system, one drip line is buried at 3-inch (7.5 cm) deep, 1 ft away from the tree row at each of the north and south sides of the tree row. An additional line may be installed at one ft away from the existing line on each side as trees grow. Each of these lines is connected to a pressure
during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and

2. Under Ground Single-Line Drip:

In this system only one drip line is buried at 3 inch deep right along the tree rows. This line is connected to a pressure regulator to keep the water pressure constant at 20 PSI. Emitters are located at 0.45 m spacing and each emitter delivers 0.6 gal water per hour. The drip line on the north side of the tree is “off-center” with the line in the south side to have a better water coverage.

Performance of 'Gala' on Different Rootstocks and Drip and Sprinkler Irrigation Systems (Objective 3):

'Pacific Gala' trees on five rootstocks were planted under drip and micro-jet sprinkler systems at 1.52 x 4.27 m (5 x 14 ft) spacing at the University of Idaho Parma Research and Extension Pomology Program Orchard during spring and summer of 2002. Therefore, in this part of our comprehensive project, we are studying effects of drip and micro-jet sprinkler irrigation systems and four rootstocks on tree growth, precocity, fruit quality attributes, and other physiological measurements under conditions of southwest Idaho which are very similar to those of Yakima and some other location in Washington. The experimental design in this portion of our projects will be a randomized complete block, split plot design with two irrigation regimes (drip and sprinkler) as the main plots, and five rootstocks (Bud 9, RN 29, Support 4, and G 30) as sub-plots, with five blocks containing nine trees per treatment. In sprinkler lines of this experiment, we have 20 PSI medium flow regulator with Olson sprinklers that provides about 9.7 GPH with 13.62 ft radius. In the drip line of this experiment, we have 20 PSI regulator at the beginning of each tree row. We have two drip lines for each tree row (one on each side of the row). Each drip line is buried at 3 inches deep, one ft away from the tree rows. An additional drip line may be installed on each side as trees grow. For each drip line, we have 20 PSI regulators. Drip emitters are spaced at 1.5ft and two drip lines of each row are “off-centered” to provide better water efficiency and coverage. Drip lines are located 12 inches from the trees on each row. Each drip emitter delivers 0.60 gallons per hour. There is no research on the performance of different apple rootstocks under different irrigation system, and thus, this objective will provide valuable information.

Fertigation Systems, General Orchard Conditions, and Cultural Practices for Objectives 1, 2 and 3:

In all irrigation systems and treatments of this project, an independent fertigation line is installed, so that each treatment can be individually or collectively fertigated. It was a major task to install such a precise and flexible system for all treatments, considering the large number of treatments used in this project (all together, 21 fertigation zones are installed). Soil is sandy loam with pH of about 7.6. Application of micro-nutrients, pesticides and herbicides and other cultural practices will be similar to those in commercial orchards. Trees are planted in east-west orientation. All trees in this project were fertigated with nitrogen at 60 kg.ha⁻¹ in 2002 and 90 kg.ha⁻¹ in 2003. In 2004 and then after, 60 kg.ha⁻¹ will be applied to all irrigation treatments. One 3.65 m (12 ft) supporting post is placed next to each tree [24 cm (2 ft) in the ground and 3.05 m (12 ft) above the ground]. The main trunks are tied to the support posts twice during each of the 2002 and 2003 seasons. 4-5 lateral branches were selected and tied at about 45 o angle from vertical central leader with cotton twins to stimulate lateral branching and earlier production. Drip and sprinkler lines are cleaned with chlorine once a month during growing season. A centrifuge sand separator and two fine-meshed filters are installed to prevent sand entering into the system. Although the flow rights are very consistent, water delivery in each irrigation station and each treatment are regularly checked to assure correct water calculation.

Water usage, Tree Growth and Development, Mineral Element Measurements, Yield, and Fruit Quality and Maturity for Objectives 1, 2, and 3:

In 2002, amounts of needed water was determined by monitoring weekly evapo-transpiration (ET) and using ETc (crop evapo-transpiration), where ETc = Kc x ET. In this calculation, the crop water use coefficient (Kc) = mature tree Kc + %M or Kc = Kc base + % M x (mature Kc − Kc base), as described by Ley (1994). %M is a measurement of canopy size. Water status of soil will be determined Aqua-Pro and TDR water sensors and a portable moisture meter. During 2002 season, Kc = 0.4 was used for all irrigation calculations. In 2003, ET r (alfalfa-based evapo-transpiration) from Agri-Met for Parma area was used and Kc was calculated, using a proper ground shading and canopy maturity. At the end of 2003, canopy ground shading was 35%. Early and late in the season during 2003 when soil moisture was in excess of what ETc showed, then a soil factor of 0.77 was used and

regulator to keep the water pressure constant at 20 PSI. Emitters are located at 0.45 m (1.5 ft) spacing on each line and each emitter delivers 0.6 gal water per hour. The drip line on the north side of the tree is “off-center” with the line in the south side to have a better water coverage.
ET a was calculated as ET a = ET c x 0.77. In 2004, since trees are more mature with larger canopy, only ET c will be used without any soil factor.

Extensive soil samples were taken before and after several irrigation periods and all physical and chemical characteristics of the soil, such as Field capacity, Bulk Density, Sand, clay, and silt content, and water penetration were determined in our lab. Regression equations were developed. Several access tubes were installed at different replications of each irrigation system and water deficit before each irrigation was determined, using the regression equations. These deficit were compared with the ET c values determined for each irrigation system at each irrigation time. Drip systems were irrigated twice a week but sprinklers were irrigated once a week.

Tree growth (growth in trunk cross sectional area), yield, time of terminal bud formation, and leaf and fruit mineral concentrations and content will be measured annually (fruit minerals will be measured when trees are in full production). For leaf mineral analysis, thirty leaves per tree will be sampled randomly from the middle of the current-season's shoot in mid-August each year. Leaves will be washed in a mild Liqui-nox detergent solution, rinsed with distilled water, and dried in a forced-air oven at 65°C. Leaves will be weighed before and after drying, and percent dry weight will be calculated. Dried leaves will be ground to pass a 40-mesh screen. Five fruits per tree will be washed with a mild detergent solution and rinsed in de-ionized water. Each fruit will be peeled and cut longitudinally to collect flesh and peel tissues and dried at 65°C. Nitrogen concentration and content of leaf and fruit tissues will be determined by combusting dry tissues using a LECO Protein/Nitrogen Analyzer (Model FP-528, LECO Corp., St. Joseph, Mich.). Tissues will be analyzed for potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) by dry ashing at 500°C, digestion, and atomic absorption spectrophotometry (Perkin-Elmer B1100, Norwalk, CT, USA) as described by Chaplin and Dixon (1974) and Jones (1977). Leaf and spur photosynthesis, stomatal conductivity, and other gas exchange parameters may be measured, if graduate students are available.

Thirty-four fruits from each tree will be picked randomly at commercial harvest time (between 17 to 20 Oct.) every year. Fruits will be divided into two groups, weighed, and placed in perforated polyethylene bags. Fruits from one bag will be tested for various quality attributes at harvest. The second bag of fruit will be stored at -1°C with about 90% relative humidity for five months and then evaluated for quality.

Fruit color will be rated visually on a scale of 1 = 20% pinkish-red progressively to 5=100% pinkish-red. Fruit firmness will be measured at harvest and after storage on three peeled sides of each fruit using a computerized Fruit Texture Analyzer (Guss, Strand, Western Cape, South Africa). These fruits then will be cut equatorially. One wedge from the calyx-end half of every fruit will be juiced, and the soluble solids concentration (SSC) will be measured by placing three to four drops of juice on a hand held, temperature-compensated refractometer (Atago N1, Tokyo, Japan) both at harvest and after storage. The stem-end half of the fruit at harvest will be dipped in KI solution, and the starch degradation pattern (SDP) for each fruit will be recorded by comparison with the SDP standard chart developed for apples.

To evaluate the effect of irrigation systems and rootstocks on fruit maturity, five randomly selected apples from each tree will be weighed and then placed in 20 x 28 x 28.5-cm closed chambers. The temperature of the chambers will be maintained at 22.8°C. Air samples with a constant flow rate of 80 mL·min⁻¹ will be drawn from the ripening chambers every 24 h to measure concentrations of evolved ethylene and carbon dioxide (CO₂) by gas chromatography. Samples will be injected into a gas chromatograph (Hewlett Packard 5890 Series II, Lionville, Pa.) equipped with a flame ionization detector and a HayeSep Q, 80/100 packed column (Alltech Inc., Deerfield, Ill.).

This study will clarify the relationship between leaf and fruit nutrient status and fruit quality of ‘Fuji’ and ‘Gala’ trees under different irrigation regimes and ‘Gala’ trees grown on different rootstocks.

The assumption of normal data distribution will be checked by computing univariate analyses for all tree responses in this study. Analyses of variance will be conducted by using SAS (SAS Institute, Cary, NC, USA), and means will be compared by least significant difference (LSD) at P ≤ 0.05. Categorical data such as fruit color will be analyzed by categorical modeling, using either PROC CATMOD or PROC GENMOD in SAS.
Budget Information

Title:
Water Use, Fruit Quality, Tree Growth and Development, and Nutritional Physiology as Influenced by Irrigation Systems in ‘Fuji’ and ‘Gala’ Apples and by Rootstock in ‘Gala’

Principal Investigator:
Dr. Esmaeil "Essie" Fallahi, Professor and Tree Fruit Physiologist

Project Duration: March 2004-December 2006
Note: This project was funded for only $25000 in 2003 and was considered only a “one year” project. Therefore, this project is submitted again for a 3-year funding. During 2003, trees were young but in 2004, we will evaluate fruit quality, yield and other factors as described in the new proposal.

Current Year: 2004

Project Total (2003 only): $25000
The following table shows how 2003 was spent:

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* Salary is for technical assistants and FB for that is 45%
** Wages are for various part of this project conducted by part-time helpers
*** Travel includes mileage charges for local and regional travel related to the project. We use the university motor vehicle and they charge us 35 cents per mile