Irrigation
FACTSHEET

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Using Irrigation for Tree Fruit Cooling

The Need for Crop Cooling

Jonagold and other new apple varieties being introduced into British Columbia are susceptible to sunburn damage. The damage occurs when the surface temperature of the fruit gets too hot for an extended period of time. A single day of exposure to high temperatures is sufficient to damage the fruit.

High temperatures damage the fruit tissues and result in a burnt or discoloured area. Preventative measures that can be taken include selective pruning to provide shade, shade cloth, anti-transpirant compounds sprayed onto the tree and cooling by irrigation.

While research has not been conclusive that evaporative cooling is effective, many growers have indicated improvements in reducing sunscalding, reducing moisture stress and improving fruit colour.

To ensure best performance is achieved, a grower should understand the mechanics and requirements of an evaporative cooling system.

Cooling Mechanisms

The application of water to a crop utilizes three methods of cooling.

1. Convective cooling occurs by evaporation of the water in air, cooling the air which then cools the crop. Fogging systems are a good example of this method. Usually these systems must run continuously or very frequently thereby enhancing disease problems. Convective methods are not very effective.

2. Hydro cooling applies cold water directly to the tree and removes heat from the leaves and fruit by heat transfer from the crop to the water. Overhead irrigation systems with high application rates are an example of hydro cooling. The large volumes of water required by this method can result in water wastage, water logging of the soil and leaching of valuable nutrients.

3. Evaporative cooling extracts heat from leaves and fruit surfaces when water applied in liquid form is converted to vapour. This method of cooling is the most effective.

Water applied to crops use one or more of the above mechanisms. The climatic conditions, method of application, duration and rate at which the water is applied will determine the relative contribution of each method. An effective irrigation cooling system will strive for as much evaporative cooling as possible.

Crop Cooling Parameters

Evaporative cooling can reduce plant heat stress by lowering plant temperature, raising relative humidity and reducing plant transpiration. The cooling lowers fruit temperature which helps to reduce sunscalding on apples. The effectiveness of the system will depend on relative humidity, wind speed, system application rate and the growers ability to ensure the system is operating correctly for the duration of the season.

The following guidelines should be followed for operating a crop cooling system:

- Depending on the variety, sunscalding on apples can occur at surface temperatures exceeding 30°-40°C. Direct sunlight can cause apple skin temperature to increase above 50°C, even though air temperature is much lower. The system should be turned on when fruit temperature reaches 2°C below the critical temperature. The turn off temperature will depend on the cycle time to the cooling system. A safe turn off temperature would be below 30°C. If crop core temperatures are used the critical temperature should be decreased by 5°C.

- The crop cooling system should be started based on crop skin temperature, not air temperature. A temperature probe inserted through the fruit, from the shady side to just below the skin on the side exposed to the sun is the best method of measuring skin temperature.

  A cooling system based on temperature sensors will require some method of interfacing the sensors with a controller to automatically start and stop the cooling cycles. The serving system must have adjustable ON and OFF temperature settings as well as a method of turning the controller ON and OFF when these temperatures have been reached.

  Fruit skin temperature can also be measured by imbedding the sensors in an artificial medium with similar thermal properties of the fruit. This avoids problems of fruit decay or not being ideally exposed to sunlight or cooling water. Green coloured agar gel in a plastic cup is one alternative.

- The objective of a spray cooling system is to prevent the fruit temperature from rising above the critical temperature, rather than cooling the fruit down after it becomes too hot.

The irrigation system must apply water frequently enough to maintain the fruit surface temperature below the critical temperature. If a large cyclic increase and decrease in fruit temperature occurs, the fruit may be more susceptible to burning. Once the decision to crop cool is made, the crop **must** be cooled the entire season. **If one day is missed the crop is more susceptible to damage than if no cooling had been done at all**.

- For best efficiency the spray cooling system should be divided into several zones and cycled in sequence. This reduces the peak flow requirements of the system. The off times should be as short as possible. In humid areas the cycle times can be slightly longer than drier areas. A maximum of three zones is recommended in the Okanagan and four to five zones for the Fraser Valley.

- Water application should maximize evaporative efficiency while minimizing total water application. The cycle time should be as short as possible to prevent the surface temperature from exceeding the critical value during the off time between cycles. Pulse the water so that free water is continually evaporating from the fruit and leaf surface.

- Evaporative cooling is most effective in low humidity conditions. The wet bulb temperature is the minimum cooling that can be achieved with spray cooling. In very humid conditions the wet bulb temperature may exceed the critical fruit temperature in which case the cooling system will have little effect. During these conditions the system should be shut off to prevent excessive soil moisture conditions from occurring.

- Evaporative cooling does not replace an irrigation event. If done properly very little water should reach the soil surface. While evapotranspiration rates will be diminished during cooling events, adequate soil moisture must be maintained to achieve full benefits of cooling techniques. E.T. rates may be reduced by 15%-20% during cooling system operation.

Improving Red Colour

Red pigment is enhanced in fruit at 70%-80% of full sunlight plus a combination of day temperatures less than 27°C and night time temperatures less 10°C. Some growers feel that cooling may be beneficial to colour enhancement. For colour improvement cooling should start four weeks prior to harvest. Cooling should begin 30 minutes prior to sunset and continue for 60 minutes after sunset.

Water Analysis

Crop cooling to be most effective allows water to be evaporated quickly from the crop. This results in conditions that allow for chemical residues to be deposited on the fruit. Water quality should be analyzed before evaporative cooling is attempted. The primary concern is the precipitation of calcium carbonate. The following parameters are important:

- **pH** - A pH level above 7.8 may indicate a potential problem with carbonate or bicarbonate precipitating.

- **EC** - EC is a measure of the total salt content. Soluble salts can be left behind on the plant and soil surface as the cooling water evaporates. Levels of EC above 3 mmhos/cm or greater should be used with caution in arid climates.

- **Calcium / Magnesium**
  High concentrations of calcium (Ca) and magnesium (Mg) will indicate a good potential for precipitates to form on the fruit. Concentrations of these ions of approximately 50 mg/L is an indicator that lime deposits are likely.

- **Carbonate and Bicarbonate**
  Carbonate (CO_3) or bicarbonate (HCO_3) levels of 100 mg/L are also a good indicator of lime deposition potential.

Procedures are available for calculating whether a deposit will occur based on the chemical analysis of the water. The procedure is outlined in the Appendix at the back of this note.

Irrigation Design for Crop Cooling

Using an irrigation system for crop cooling will increase overall water use. Crop cooling may result in a 30% decrease in the evapotranspiration rate of the crop while cooling is taking place but will not provide any appreciable moisture for irrigation purposes.

Water Availability

The water source capacity will determine the amount of crop cooling that can take place. Crop cooling will usually be required during the time of peak irrigation demand. Growers that receive water from an irrigation district will be limited to the amount of water that can be taken at one time. The peak flow rates have been established to ensure that sprinkler irrigation systems can supply the evaporative demand on a 24-hour basis. To make water available for crop cooling will, therefore, usually require the installation of a drip irrigation system to conserve irrigation water. A 35% saving is achievable. **The sample plan at the end of this factsheet provides operation details of a crop cooling system on an irrigation district supply**. Note that only $^{1}/_{3}$ of the acreage can be cooled due to water supply limitations.

Sprinkler System Design Guidelines

The following design guidelines should be followed for a crop cooling system:

- To maximize water availability for crop cooling, the trickle system must be designed to operate at the peak water supply capacity. The emitter discharge rate and spacing must be selected to ensure that the zone size uses the peak system flow rate.
- The irrigation system must be designed to suit the crop cooling requirements. Do not use a system that has been designed for irrigation purposes. Application rates are generally higher for irrigation purposes than for cooling requirements.
- Hydro-cooling or excessive applications should be avoided. Problems with excessive soil moisture may develop that could cause root and crown diseases.
- A crop cooling system will require application rates of 0.13 to 0.18 in/hr to achieve best results. This converts to flow rates of 60 - 80 gpm/acre for systems that provide head to head coverage.
- No protection is provided for systems that are less than 0.09 in/hr (40 gpm/acre on a head to head system). It is, therefore, better to divide the orchard into three 60 gpm/acre zones that are being cycled than to have one 20 gpm/acre block operating continuously.
- Droplet sizes should be large enough to penetrate the canopy and wet all crop surfaces.
- Rapid wetting of the fruit and letting the water evaporate directly from the surface is most effective in reducing fruit temperatures and will conserve water. The system must be controlled to pulse, or cycle the water applications based on a time sequence or on fruit temperatures.
- Cycling times for the Okanagan should not exceed more than 1/3 ON and 2/3 OFF. The maximum number of zones should therefore not exceed three. Operating times should not exceed 20 minutes ON and 40 minutes OFF. If application rates are lower than 0.13 in/hr the cycling times must be shorter, maximum of 5 - 10 minutes ON and 10 - 20 minutes OFF. In other regions the maximum number of zones that can be cycled should not exceed 5. The maximum off time should not exceed 40 minutes.
- Total water use for the farm will increase by 25% - 40% with a functional crop cooling system. Cooling is a very inefficient use of the water.

Microsprinkler Systems

Microsprinkler and microjet systems offer some advantages in that the tree canopy can be wetted without applying water in the panels where it is not required. These systems also operate at lower pressures, which may be an advantage in some situations. The design guidelines are similar to the sprinkler systems:

- Application rates should be 0.13 - 0.18 in/hr. Since only the tree is wetted the flow per acre can be reduced to as low as 40 gpm/acre.
- Operating pressures should be in the 20-30 psi range.
- Since droplet sizes may be smaller, the cycling times may need to be quicker. Cycling times of 5 minutes ON and 10 minutes OFF are suggested.

Further information is available from:
Tree Fruit Irrigation
Good Fruit Grower P.O. Box 9219
Yakima, Washington USA 98909

Evaporative Cooling of Apples by Overtree Cooling
ASAE Paper No. 932060

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APPENDIX

Calculating Lime Deposition Potential:

A water sample must be taken and analyzed for pH, Ca, Mg, Na, K, HCO_3, and CO_3. These water quality parameters for some of the irrigation districts can be found in the B.C. Trickle Irrigation Manual. The lime deposition probability can be calculated by determining pHc, a theoretical pH of irrigation water in contact with lime and in equilibrium with soil $C0_2$. If the pH is higher than pHc, it is likely that lime will precipitate.

Use the following tables and formula to calculate the pHc.

$$pHc = p(Ca+ Mg + Na + K) + p(Ca + Mg) + p(C0_3+HC0_3$$

Element	mg/L per meq/L
Ca	20
Mg	12
K	39
Na	23
$C0_3$	30
$HC0_3$	61

Table 1 Factors for converting mg/L to meq/L

Converting to meq/L

Ca	110 mg/L	=	5.5 meq/L
Mg	48 mg/L	=	4.0 meq/L
Na	26 mg/L	=	1.1 meq/L
K	3 mg/L	=	0.08 meq/L
$C0_3$	1 mg/L	=	0.03 meq/L
HCO_3	280 mg/L	=	4.6 meq/L
PH	8.1		

Example: A water sample has the following results:

From Table 1: **pHc = p(Ca+ Mg + Na + K) + p(Ca + Mg) + p($C0_3$+$HC0_3$)**

p(Ca+ Mg + Na + K)	p(Ca + Mg)	p($C0_3$+$HC0_3$)
↓ (5.5+4.0+0.08+1.1)	↓ (5.5 + 4.0)	↓ (0.03 + 4.6)
↓ = 10.7	↓ = 9.5	↓ = 4.63

From Table 2:

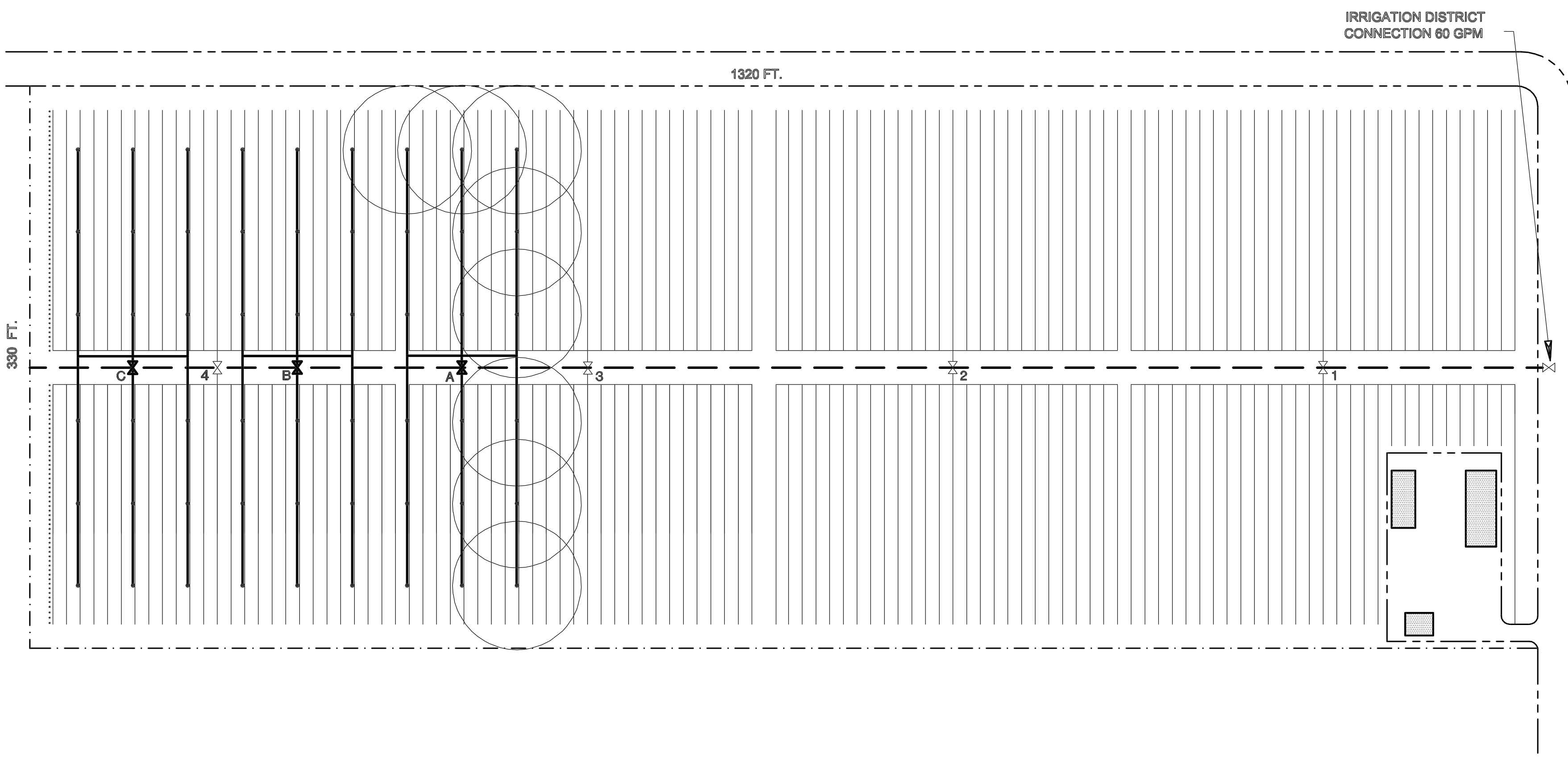
p(10.7)	⟶	p(Ca+Mg+Na+K)	= 2.3
p(9.5)	⟶	p(Ca+Mg)	= 2.3
p(4.63)	⟶	p($C0_3$ + $HC0_3$)	= 2.3
		Total	= 6.9

pH - pHc = 8.1 - 6.9 = 1.3

Since this value is positive it is likely that lime deposits will form on the fruit as a result of crop cooling.

Sum of Concentration meq/L	p(Ca+Mg+Na+K)	p(Ca+Mg)	$p(C0_3+HC0_3)$
.05	2.0	4.6	4.3
.10	2.0	4.3	4.0
.15	2.0	4.1	3.8
.20	2.0	4.0	3.7
.25	2.0	3.9	3.6
.30	2.0	3.8	3.5
.40	2.0	3.7	3.4
.50	2.1	3.6	3.3
.75	2.1	3.4	3.1
1.00	2.1	3.3	3.0
1.25	2.1	3.2	2.9
1.5	2.1	3.1	2.8
2.0	2.2	3.0	2.7
2.5	2.2	2.9	2.6
3.0	2.2	2.8	2.5
4.0	2.2	2.7	2.4
5.0	2.2	2.6	2.3
6.0	2.2	2.5	2.2
8.0	2.3	2.4	2.1
10.0	2.3	2.3	2.0
12.5	2.3	2.2	1.9
15.0	2.3	2.1	1.8
20.0	2.4	2.0	1.7
30.0	2.4	1.8	1.5
50.0	2.5	1.6	1.3
80.0	2.5	1.4	1.1

Table 2 Calculation of pHc terms (From Stroehlein & Tisdale, 1975)



TOTAL ACREAGE = 10 ACRES

IRRIGATION DISTRICT WATER SUPPLY = 60 GPM

TRICKLE IRRIGATION SYSTEM

TREE SPACING 4 FT. x 12 FT.
E.T. = 0.24 IN./DAY
PLANT WATER REQUIREMENT = 6.8 G/P/G
70 TREES/ROW
4 L/HR. EMITTERS SPACED @ 2 FT.
26 ROWS/ZONE
OPERATING TIME = 3.4 HRS/ZONE
TOTAL OF FOUR ZONES (1-4)
TOTAL TRICKLE OPERATING TIME = 13.6 HRS/DAY

CROP COOLING SYSTEM

APPLICATION RATE FOR CROP COOLING = 0.13 IN./HR.
SPRINKLER SPACING 48 FT. x 48 FT.
NOZZLE 1/8" @ 47 PSI - 80 FT. WETTED DIAMETER
FLOW RATE = 3.11 GPM/SPRINKLER
MAXIMUM ZONE SIZE IS 18 SPRINKLERS
TOTAL OF THREE ZONES OPERATING IN SEQUENCE (A-C)
AREA COVERED BY CROP COOLING IS 3.5 ACRES

OPERATING TIME AVAILABLE FOR CROP COOLING = 10 HOURS @ 60 GPM TOTAL FLOW

NOTE

IRRIGATION SYSTEM PARAMETERS SHOWN ARE FOR SPECIFIC SITE CONDITIONS.

THIS PLAN IS TO BE USED FOR ILLUSTRATION PURPOSES ONLY.

B.C. Ministry of Agriculture, Fisheries and Food
RESOURCE MANAGEMENT BRANCH

CROP COOLING OPERATION ON IRRIGATION DISTRICT WATER SUPPLY

DATE	JULY 1995	SCALE	NTS
DESIGNED	T. VAN DER GULIK	SHEET	1 OF 1
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