FERTIGATION GUIDELINES

IN

HIGH DENSITY APPLES

AND

APPLE NURSERIES

IN THE

OKANAGAN – SIMILKAMEEN

Revised: March 2001

British Columbia
Ministry of Agriculture,
Food and Fisheries

Okanagan Valley Tree Fruit Authority

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Contents

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FERTIGATION GUIDELINES IN HIGH DENSITY APPLES AND APPLE NURSERIES IN THE OKANAGAN – SIMILKAMEEN

Introduction:

Research work in the last eight to ten years has led to greater understanding of nutrient use by fruit trees. The uptake of nutrients by the plant, partitioning of nutrients in the plant and the use of fertilizers with irrigation water has been investigated by a team of researchers at the Pacific Agriculture Research Centre at Summerland. This work and related work done around the world is the focus of this manual. An understanding of tree nutrient use and timing of nutrient uptake allows more efficient use of water and fertilizer and minimizes potential environmental impact. A major addition to this manual is the use of fertilizers in scheduled irrigation. Changes to previous nutrient recommendations on fertigation with fixed irrigation cycles have been made. There is a greater emphasis on foliar feeding, throughout the season but particularly post harvest and pre-bloom.

DEFINITION:

Fertigation is the application of fertilizers through an irrigation system by the use of "T" tape, drippers, micro-jets, sprinklers, etc.

ADVANTAGES:

- Fertigation ensures the fertilizer will be carried directly to the root zone. Amounts and timing of fertilizer application can be precise.
- Moving fertilizer into the root zone can be a problem in low rainfall areas. Fertigation with drip over comes this difficulty.
- Studies on local soils by PARC scientists have shown that compared to broadcast applications, dramatically less fertilizer needs to be used to achieve similar growth and yield due to direct application to root zones when using fertigation.
- When using fertigation combined with scheduling of irrigation there may be savings of up to 50 percent of the amount of water is used, compared to a fixed irrigation schedule. Dependent on soil type, leaching of nutrients into the ground water can be reduced.
- Compared to some forms of sprinkler irrigation or fertigation with a fixed irrigation schedule, scheduling of water use with fertigation still results in the same amount of fertilizer uptake by the tree. However efficiency of fertilizer use improved from 10 to 38 percent, in some studies.
- There is often enhanced growth and yield from years 2 to 4 but not later compared to broadcast.
- Fertigation allows for increased flexibility at reduced rates of fertilizer timed more closely to tree demand.
- Compared to broadcast application of fertilizer, fertigation of phosphorus and potassium allows rapid movement into the root zone.

- Uniformity of application mentioned below is much less of a concern when daily applications are made using automated systems and even less so when low amounts of fertilizer are applied for the entire irrigation cycle. This approach also assists in reduced leaching of nutrients providing water is not over applied.

DISADVANTAGES:

- Uniformity of application depends on uniform water distribution. Poor system design, plugged lines and emitters means poor distribution.

- Amounts cannot be varied to suit individual tree requirements.

- Only soluble forms of fertilizer can be used. (See Table 1)
  Soil acidification is a significant problem with the use of any acid fertilizers regardless of application method particularly in poorly buffered soils, and low pH soils. This problem is intensified with drip irrigation. An acidification index (ARI) has been established and can be requested when soil samples are analyzed, to determine how sensitive soils are to rapid acidification

- Some nutrients are leached readily, particularly nitrogen, boron and sometimes potassium particularly in coarse textured soils.

- Roots are generally restricted to areas close to the emitter, especially so in coarser soils with dwarfing rootstocks such as M9 and M26 particularly when ideal moisture and soil nutrient conditions exist. In these restricted root systems pH decreases more quickly with the use of acid fertilizers, as well by the third year of use there is usually lower extractable magnesium and potassium. Such potassium deficiencies may contribute to slower growth of drip irrigated trees in later years. (leaf K analysis is a good indicator of K- deficiency)

- Over cropping especially in the early years limits vegetative growth, can virtually stop root growth and may add to some of the disadvantages mentioned above. As fruit numbers increase, fruit size and shoot leaf size can decrease. Leaf size may be related to current nitrogen supply which could be decreased when root growth is restricted.

- A smaller root volume may result in uptake difficulties for non-fertigated non-mobile nutrients, such as copper whose uptake is dependent on root length.

- Some of these problems such as acidification can be overcome with the use of pH neutral fertilizers. Difficulties such as reduced root volume can be offset with the use of micro-jet sprinklers or mini-sprinklers but some of the water and fertilizer use efficiencies could be lost. New mini-sprinkler technology with restricted application diameters may be a great improvement over old technology for applying fertilizers and maintaining better root volumes at the same time. Attention to soil pH and nutrient levels in soil and leaves plus the use of various mulches may help identify and offset some of these difficulties.

NUTRIENT FEEDING
GENERAL CONCEPT:

High-density trees grown with micro irrigation and more so with drip irrigation have a relatively restricted root zone both in depth and lateral spread. Micro-sprinklers tend to have shallow roots but more lateral spread. Trees may be very productive especially in the early years of fruiting with drip and there is heavy use of nutrients in the zone occupied by the roots. In addition, due to relatively small wood and trunk volumes even in mature trees on dwarfing rootstocks, less nutrients are stored, and are thus not available to the tree during periods of stress. These types of trees will have to be supplied with necessary nutrients to obtain consistent cropping.

The newly planted trees should have been well fed in the nursery and continue to be well fed in the planting year and beyond. Nutrition management needs to be matched with other sound horticultural techniques e.g. pruning, weed control, disease control, etc. Well branched heavy caliper trees may fill their space in the planting year, but in most cases the trees need to be pushed to fill their space in year 2 and 3 as well. In addition, they will be carrying varying amounts of crop.

In the Okanagan-Similkameen we have growing conditions that are peculiar to our area. For example:

Fall planting: We generally don't fall plant due to potential winter damage and therefore can't take advantage of early root growth.

Soils: Our soils vary greatly from light, sandy, gravely to heavy clays but we have a high proportion of coarse textured soils.

Temperatures: Our high early summer temperatures combined with water stress and excess crop loads can stress trees to the point of reducing fruit size, leaf size and of stopping or reducing vegetative growth.

Water: A hot climate and low humidity create greater evapo-transpiration demand.

Winter: We need to manage water, and nutrient timing as well as crop load so as to achieve adequate growth and still be able to harden trees off for the winter, support nutrient storage and positively influence spur leaf size, and fruit set the following season.

Scheduled irrigation:

Irrigation scheduling combined with fertigation is a major concept addition to this manual and has been alluded to earlier in the text.

A well managed scheduled irrigation system makes the most efficient use of water by applying water at the right time and place while minimizing losses to evaporation runoff and deep percolation. In the case of fertigation, scheduling minimizes leaching losses to the ground water and supplies water and nutrients to meet daily requirements. Good management of water is critical to maintaining growth. Roots are stressed if there is insufficient water and air space is created around roots. This situation does not allow for the transfer of water and nutrients to the plant. There is an overall effect of reducing and or shutting down carbohydrate production, which provides the motor to enable active uptake of nutrients by the roots. Scheduled irrigation starts in the spring with soils filled to field capacity. In other words the water bank balance needs to be full. As water is used by the trees and evaporates it is replaced or topped up on a daily basis.

Sustaining fruit growth and fruit quality and healthy large spur leaves as well as adequate shoot growth is critical. Scheduling irrigation by measuring soil moisture in some way, as well as observing and measuring meteorlogical information, maintains good plant water and nutrient relationships.

Research at P.A.R.C. has shown that scheduling irrigation can result in between thirty and thirty-eight percent efficiency of nutrient use as opposed to fifteen to eighteen percent efficiency for fixed irrigation cycles. Essentially less than one-half the water and nutrients are used while achieving the same or better growth and yield. Such savings, of course are dependent on the extent to which current irrigation practices don't match tree demand.

There are a number of methods of measuring soil moisture, including the hand feel method, tensiometers, and electrical resistance blocks. The collection of meteorlogical data using evaporimeters and evaporation pans (including the atmometer) can help match plant water use and evaporation. P.A.R.C. scientists used an Atmometer to develop the data used for schedules in this manual. (Soil moisture assessing methods are detailed in the B.C. Trickle Irrigation Manual).

The guidelines that follow are exactly that, "Guidelines". How your trees are performing, the crop load that they carry, and the soil and growing conditions present may require adjustments to the guidelines. Leaf analysis must be used to determine and gauge tree performance, and soils must be monitored regularly. Please refer to the nutrition section of the Tree Fruit Production Guide for additional information.

NURSERY:

For many growers the definition of nursery has changed. It can now refer to permanent plantings where bench-grafts or sleeping eyes are used as plant material. Which must be treated as nursery plants. There is also the traditional system for nursery where rootstock are planted and summer budded and which then can be grown as trees or dug and transplanted as sleeping eyes.

Regardless of nursery type, soil analyses should be conducted to determine whether any pH adjustments or amendments are required. In addition to good pre-plant preparation with a spader, fumigation may be required if apples were recently on the site. Also apply a fall Glyphosate (Roundup or Touchdown) and pre-plant herbicide as well as a complete fertilizer such as 13-16-10 or a super-phosphate at approximately fifty pounds of nitrogen to the acre.

Rootstock to be summer-budded:

Purchase a moderate caliper stock of 7 mm to 9 or 11 mm. Heavy caliper stocks are not desirable. Rootstocks should be grown with a moderate level of vigour. Extra phosphorus at approximately 15 grams of P_2O_5 per plant should be fertigated as the buds start to push, so that the phosphorus is in place for root growth. As shoots start to push, start to apply nitrogen. To ensure moderate growth use only five to ten grams of nitrogen from late May through June. It is not usually necessary to push rootstocks for summer budding by fertigating into July, unless there really has not been satisfactory shoot growth. Some potassium should be added by using potassium nitrate as the nitrogen source during the last week of June. Two or three complete foliar spray applications can be made, but the plants must not be pushed too hard.

Sleeping Eyes and Bench-Grafts: (in permanent place or to be dug and transplanted).

This plant material should be pushed more vigorously to obtain adequate early growth with time to harden off for winter. Use the same phosphorus program as above but boost the nitrogen levels to ten to 20 grams of nitrogen per plant from calcium nitrate. Nitrogen should be fertigated to mid-July. Plants should be fertigated with ten to fifteen grams Potassium through July and August. Note although better growth should be achieved with calcium nitrate, 10-34-0 or 10-52-10 (these are soluble materials) can be used especially if the plants are going to be moved and there is not concern about soil acidification. In addition a full weekly foliar program is advised as soon as leaves open.

PRODUCING TREES

General:

As trees fill their space and move to a more productive phase, nutrient requirements are essentially dependent on how much of the nutrient is removed by the crop. Some soils, but not all, provide enough nutrients to meet tree requirements in terms of growth, and there is only a need to feed according to the crop.

Generally, the tree requires adequate nutrition to provide renewal wood, healthy leaves, spurs and flowers and to produce good-sized, well coloured, sound fruit.

Monitoring:

Leaf analysis* and monitoring the soil situation are critical aspects of determining how much of each nutrient is required under our climate and cropping and management conditions. ***Please note that minor elements such as zinc, boron, and magnesium are most effectively applied as foliar sprays. Under most conditions this also applies to calcium. (*Fruitlet analysis would also add information for nutrient needs). (In addition please consult the nutrition section of the Tree Fruit Production Guide).**

VEGETATIVE / FRUITING BALANCE

As a good balance between cropping and vegetative growth is achieved, less nitrogen per kg of fruit is used, although more total N is required to produce a 45 bin/A crop as opposed to a 20 bin/A crop. Good, consistently cropping trees have proportionately less vegetative extension. There is less demand for calcium, i.e. a better leaf to fruit ratio. High leaf to fruit ratios, that is, lots of vegetative growth and a light crop, particularly under low humidity conditions, create a heavy leaf demand for calcium. Calcium may therefore be reduced in the fruit as well.

First Year to Mature Producing Trees:

Nitrogen:

Apple trees start the new season drawing on reserves of stored nitrogen. The use of storage nitrogen is largely finished at the start of rapid shoot growth and can provide most of the nitrogen required by spur leaves, around fifty percent of the nitrogen for shoot leaves and sixty percent of the nitrogen in the fruit. Healthy large spur leaves are critical as they provide most of the carbohydrate for fruit and fruit bud development.

Tree Uptake of Nitrogen:

Apple trees use relatively small amounts of nitrogen. Apple trees also have quite low root numbers compared to other plants and this is especially so for dwarf apples. This fact coupled with an inefficient irrigation system means that considerably more nitrogen needs to be supplied than the tree actually requires. This is where irrigation scheduling comes in. Scheduled irrigation coupled with fertilizer injection throughout the irrigation period maintains a relatively low concentration of nitrogen in the irrigation water. When only the daily requirement of water is applied, nutrients tend to stay in the root zone longer making for a more efficient use of both water and fertilizer. As trees grow larger they take up more water and therefore more nitrogen; enough to meet daily growth needs of crop, shoots and foliage.
Nitrogen is not taken up before rapid shoot growth begins. Generally this takes place seven to ten days after full bloom, although some varieties such as Fuji for example, will start rapid shoot growth during bloom. To use nitrogen efficiently, it should not be fertigated until rapid shoot growth starts. The fertigation schedules presented start at that time and are completed by mid July at the latest. This schedule should be maintained in young trees; and may also be necessary for some production trees. But this can be affected by variety, crop load, shoot growth, leaf colour, and the history of fruit colour development and its synchronization with fruit maturity, as well as soil fertility. Some varieties will require only four to eight weeks and some like Jonagold virtually no extra nitrogen beyond some post harvest or pre-bloom foliar nitrogen.

Nutrient uptake and soil moisture:

Soil moisture must be adequate when rapid shoot growth starts. Root growth requires daily supplies of carbohydrate from leaves and many nutrients require carbohydrate for active uptake. Good soil moisture is important for ongoing photsynthesis to be able to provide that carbohydrate. Scheduled irrigation is a useful way to maintain adequate soil moisture.

Pruning, Nitrogen and Roots:

Excessive tipping of one year shoots when pruning, results in lots of new growing shoot tips, which produce gibberellins, which are growth hormones. Nitrogen is the element that influences gibberellin production the most. Also excessive nitrogen supply influences the production of cytokinins by the roots, which maintain a high level of growth at the shoot tip which produce lots of gibberellins. High gibberellic acid levels tend reduce or prevent flower bud formation. Therefore relatively early use (start post bloom and end early to mid July) of nitrogen with minimal pruning techniques will result in enhanced productivity. Also excessive nitrogen nutrition increases the nitrogen concentration in the fruit to a much greater degree than in the leaves .

Form of Nitrogen:

Generally speaking, pH neutral forms are suggested such as calcium nitrate and potassium nitrate. Most other forms of NH_4 nitrogen are to varying degrees acidic (see the Tree Fruit Production Guide for more information.) For high pH soils, acidic forms may be useful to assist in pH reduction. In the spring soil temperatures can be cool and soil organisms are not particularly active for conversion of ammonium forms of nitrogen to nitrate. In addition the ammonium ion is somewhat antagonistic to the uptake of calcium at the critical post bloom timing. (See calcium section) Also excessive ammonium is somewhat antagonistic to certain enzyme systems responsible for nitrate reduction, which incorporates into the plant.

Foliar nitrogen:

It is critical to apply urea immediately after harvesting the crop. The suggested rates of application range up to twenty –five percent of the amounts supplied through fertigation. Sixty to seventy percent of the nitrogen applied post harvest to the leaves may be moved into the tree and cycled into storage. Research has shown that these nutrient sprays can increase fruit set and yield the next spring. The fall sprays are particularly critical for development of large healthy spur leaves, which in turn are responsible for the development of strong fruit buds. This approach of combining fertigation with foliar nitrogen maximizes the use of nitrogen while reducing ground applications.

Nitrogen Fertigation Rates With Irrigation Scheduling:

Research at the Pacific Agri-Food Research Centre at Summerland has shown that applying fifty to seventy-five parts per million of nitrogen over a 8 to 12 week period is adequate for most tree growth and crop load requirements. With daily application the concentration stays roughly the same in the irrigation water and soil solution. Trees use more water as they get larger and or, there are greater evaporative demands and therefore more water and nitrogen is taken up to meet tree requirements. This means that soil solution concentration of nitrogen can remain at the same level and does not need to be increased as tree size, crop load, or evaporative demand increases.

Tree Age	**Crop load (Bins)**	**Fertigation Period** 12 weeks	8 weeks	4 weeks
1 *	**0**	**50 to 75 ppm*** **	**85 ppm**	**85ppm**
2 **	**5**	**50 to 75 ppm**	**85 ppm**	**85 ppm**
3	**15**	**as above**	**as above**	**as above**
4	**25**	**as above**	**as above**	**as above**
5	**30**	**as above**	**as above**	**as above**
6	**40**	**as above**	**as above**	**as above**

***In the planting year fertigation with nitrogen starts approximately four weeks after planting, as buds start to push and white roots are pushing. (see phosphorus section).**

Special note on Super Spindle:

Super spindle fertigation in the first leaf is difficult to judge. Push growth early in the season. Later growth tends to push too late and the danger is that those buds will not harden or set fruit buds, so crop in year two is lost or does not set. In other words, push trees hard early but back off early too, so flower buds can mature to strong healthy flowers.

As super spindle trees mature, crop nutrient levels will require close scrutiny. The system is extremely intense with high cropping capabilities. Fruit size in particular may suffer if adequate nutrition is not maintained.

** Second leaf and older Nitrogen fertigation starts at the onset of rapid shoot growth, generally seven to ten days after full bloom. Some varieties actually will start rapid shoot growth at full bloom.

*** Research has shown that generally 50 ppm is adequate but 75 ppm may be required. Leaf and fruit nitrogen should be monitored to ensure that once 4th and 5th leaf production is reached leaf nitrogen levels range from 2.0 to 2.2 percent.

<u>Note:</u> These rates of application take into account the approximate 38 % efficiency of nitrogen application with drip systems.

Nitrogen Fertigation Rates with Fixed Irrigation Cycles: (planting year)

Planting Year Timing	**Grams of Actual Nitrogen/tree/2 weeks** **Coarse Soils**	 **Fine Textured Soils**
From planting to 4 weeks	**0**	**0**
Rapid shoot growth 4 to 6 weeks	**6**	**4**
6 to 8 weeks	**10**	**6**
8 to 10 weeks	**8**	**6**
10 to 12 weeks	**6**	**4**
Total	**30***	**20***

***Rates are lower than in earlier publications. This is due to the fact more efficient use is occurring by starting to apply nitrogen at the onset of rapid shoot growth, rather than any earlier when roots are not receptive. (Also see phosphorus section) In addition the fertigation program is coupled with a weekly young tree foliar program plus urea, boron, and zinc sprays just prior to leaf fall, and a pre-bloom foliar program at the start of the second year. <u>Good practices of weed control and pest and disease control are critical to young tree growth.</u>**

Nitrogen Fertigation Rates for Fixed Irrigation cycles: (years 2 to 4)

	Grams of actual Nitrogen/tree/2 weeks					
Timing		**Coarse Soils**		**Fine Textured Soils**		
	Yr 2*	**Yr 3**	**Yr 4**	**Yr 2**	**Yr 3**	**Yr 4**
Bud burst to Full Bloom or 7 to 10 DAFB	**0**	**0**	**0**	**0**	**0**	**0**
Start of rapid shoot growth to 2 weeks	**6**	**6**	**6**	**4.5**	**4.0**	**4.0**
2 to 4 wks	**8**	**10**	**10**	**6**	**7**	**7**
4 to 6 wks	**8**	**10**	**10**	**6**	**7**	**7**
6 to 8 wks	**8**	**10**	**10**	**6**	**7**	**7**
8 to 10 wks	**6**	**8**	**8**	**4.5**	**6**	**6**
10 to 12 wks	**4**	**6**	**6**	**3**	**4**	**4**
Total	**40**	**50**	**50**	**30**	**35**	**35**

- **Year 2 will require a full fertigation schedule, plus a full foliar program mentioned above.**

****Years 3 and 4 – duration of schedule depends on growth achieved in terms of the tree filling its allotted space. Some varieties such as Jonagold, Fuji, Braeburn, Sunrise and perhaps Ambrosia may require a reduction in the schedule for year four, to 4 to 8 weeks particularly on fine textured or more productive soils. It is much better to reduce the schedule by terminating it early rather than starting late, and fertigating for a short period.**

<u>Note:</u> If Jonagold has almost filled its space, no nitrogen other than perhaps one fall foliar urea may be required by year 3 or 4. It is very difficult to reduce overall tree nitrogen in Jonagold and poor fruit quality, finish and large size will be an ongoing problem in the Okanagan. The other varieties mentioned will require a full fall foliar program. Leaf analysis, and fruit colour development timed with internal maturity need to be observed closely on all varieties.

Nitrogen Fertigation Rates for fixed Irrigation cycles for producing trees: (years 4 or 5 and older)

Crop load (Bins)	Grams N required/tree /season* (Based on annual use by leaves and Fruit)
20*	**12**
30	**16**
40	**20**
50	**26**
60	**32**

*****These grams per tree are based on 1500 trees per acre. The amounts specified should be reduced per tree for numbers greater than 1500 trees/acre, and increased per tree for tree numbers less than 1500 trees/acre**.**

Note: The amounts should be applied starting at rapid shoot growth, and divided up over a 4 to ten week period, ending no later than mid-July.

Note: Whether these rates are used at these levels is strongly dependent on leaf analysis, and fruit colour development year to year.

Note: These rates should be supplemented with a strong post harvest and pre-bloom foliar nutrient program, including urea, and boron. (growers do apply zinc post harvest, but it is not very effective compared to delayed dormant in the spring).

Note: This chart implies trees that are capable due to size, of carrying 30 to 50 bins of fruit. Trees that are capable of carrying a full crop and are carrying a lighter crop must have their nutrient schedule reduced as suggested. **But**, smaller trees that must still grow to achieve a structure that fills the tree spacing and are older than three to four years, may be carrying a heavy crop for the tree size that exists. They should have their crop load reduced as well as receiving an increased Nitrogen level to encourage the tree to fill its space.
There are varietal differences – fruit size, colouring, maturity development, susceptibility to bitter pit and maturity dates, as well as crop load on each variety, make consideration of adjusting nitrogen rates important. An attempt at a description of some of those differences has been made below:

Gala – Small apple, heavy cropping, higher demand for nitrogen.

Sunrise – Early maturing, large apple, less N for good colour and medium to large firm fruit.

McIntosh – Less N to encourage colour and reduce fruit size to encourage quality fruit.

Spartan – Small fruit size a problem, but must not have excess N, which adversely affects colour.

Jonagold – Large fruit a problem, therefore low N on low crop trees, modest amounts as crop load increases to keep fruit size in line, encourage colour and ensure less problems with biennial bearing.

Fuji – Nitrogen leaf levels must be monitored as Fuji colour is readily affected by excess nitrogen. Generally only a short program of fertigating is required.

Braeburn- this variety is prone to storage problems and excess nitrogen is negative.

NOTE: These are guidelines only! There is no substitute for careful observation. Too much nitrogen can lead to poor fruit colour and poor storage qualities, increased bitter pit, and crown and root rot of apples. Some of the rich silt soils have required very little, if any, nitrogen for mature producing trees for a number of years in a row. Vegetative growth, leaf nitrogen analysis, fruit size, and fruit colour development must be used to adjust rates of application. (Please consult the nutrition section in the Tree Fruit Production Guide for additional information.)

FOLIAR FEEDING

Many of the premixed soluble granular materials have micronutrients supplied in the mix and amounts are on the bag.

In addition, regular foliar feeding of young trees is requiredsuggested. A formulation as follows should be used at 10-day intervals until mid July. *

Dilute in 450 litres of water *

2 kg Urea (45-0-0)

1 kg 20-20-20

1.5 kg Epsom salts (Mg S04-15%)

0.1 kg Boron (Solubor)

0.9 kg zinc 50 * (only pre-bloom application on bearing trees)

* on cropping trees, there is concern about russetting fruit after bloom during cell division stage; it is best to wait until early to mid June

Phosphorus:

Phosphorus is the middle number of the three major nutrients listed on the bags of fertilizer. Phosphorus is associated with good root growth and tree establishment. Phosphorus is required early in the season, particularly during cell division stages. It needs to be in adequate supply throughout the season. It is an established practice to use phosphorus to enhance root growth and offset Specific Apple Replant Disease. In addition, adequate fruit levels of phosphorus can be linked to fruit firmness and reduced low temperature breakdown in storage for susceptible varieties. Leaf levels of phosphorus need to be at a minimum of 0.24 percent of dry weight to ensure good fruit quality at least as far as phosphorus is concerned.

Phosphorus at planting:

For a number of years it has been recommended to apply approximately 58 grams of P_20_5 per tree in the planting hole at planting. Applying and mixing a mono or diammonium phosphate in the hole solved the problem that phosphorus when applied to the soil surface did not move into the root zone readily. It was absorbed by soil particles. Fertigating with a soluble form of P like ammonium polyphosphate (10-34-0) allows the phosphorus to be available as the root growth occurs. The availability of the phosphorus is best at a soil pH 6 to 7. Above and below this range it is held more strongly or precipitated and is not as available for uptake by roots. This amount of phosphorus can be applied in one dose, but it is better to split up the total application and fertigate over one or two weeks to avoid any potential of root burn.

General fertigation of nitrogen should not start until about four weeks after planting, phosphorus can be applied a week or so prior to this. Fertigating phosphorus over a short period of three to four weeks mentioned in the last version of this manual, was suggested due to difficulties with mixing problems of phosphorus calcium and magnesium products. Therefore from a practical standpoint applying phosphorus over a one to two week period is better.

Phosphorus applications second year and older:

Recent work at P.A.R.C indicates that it may be useful to fertigate phosphorus at or right after bloom when there is a high demand as root growth is initiated for the season and fruit cell division takes place. This is followed by fertigating nitrogen from late May, to Mid July gave higher cumulative yields and higher leaf P and N. There was a stimulating effect on nitrogen uptake by the phosphorus application, probably due to improved root growth from applied phosphorus. This approach of fertigating phosphorus each year is likely useful as the soil solution contains higher phosphorus and therefore it is readily available. The situation however, should be monitored. On an ongoing basis reduce phosphorus from the planting year rate of 58 grams per tree of P_20_5 to approximately 36 grams of P_20_5 per tree. Monitor leaf and fruit levels (see the calculations section for phosphorus, also see the section in this manual on acceptable forms of phosphorus).

Foliar applications of Phosphorus:

As part of a sound fruit quality management program, foliar formulations of phosphorus are available to supplement soil applications. These can be applied starting at petal fall every one to two weeks for three or four sprays. These sprays may enhance fruit and leaf phosphorus, and optimize fruit firmness and storability. (See full foliar nutrient program).

Phosphorus fertigation rates for scheduled irrigation:

Tree age	Irrigation solution concentration
Planting year	600 ppm *
Two years and Older	500 ppm **

*Fertigating for one week at 600 ppm, irrigating with 4 litre per hour emitters, one emitter per tree for one half hour per day, or at 300 ppm for 7 days irrigating for one hour per day.
** 500 ppm for 7 days, irrigating with 4 litre per hour emitters one per tree for one half hour per day or for 7 days irrigating for one hour per day at 250 ppm.

Note: Even though this is a scheduled method of application, the full amount of 58 grams or 36 grams of P2O5 per tree should be applied. Conditions could indicate that little water should be applied under the scheduled approach, in that case switch to the fixed irrigation method.

Phosphorus fertigation rates for fixed irrigation cycles: (Planting year and older)

Tree age	Application rate*
Planting year	58 gms/P205/tree**
Second year And older	36 gms/P205/tree***

* Apply these amounts preferably in three separate doses or divide into daily doses and fertigate for one to two weeks.

** Planting year, apply phosphorus right after planting, but before nitrogen fertigation starts at approximately four weeks.

***Second year and older, apply phosphorus during the blossom period, and prior to nitrogen fertigation.

POTASSIUM:

Potassium is a major nutrient that is required in relatively large quantities, particularly in fruit trees. In general it is thought in the Okanagan that soils supply ample amounts of potassium, but with small and shallow root systems in sandy and coarse soils, deficiencies occur. This situation is intensified under drip and micro-irrigation systems.

Potassium plays a major role in enzyme reactions and protein synthesis and in particular in water relations in fruit trees. Water status in the leaves is critical. The stomata cells surround the openings in the leaves, and as long as these cells are open, which is maintained by good water, the leaves will produce carbohydrates. This is necessary for root growth, nutrient uptake, shoot and leaf growth and fruit sizing. In addition low potassium trees are more susceptible to winter cold damage and spring frost injury to buds and flowers.

Apple trees require almost as much potassium as they do nitrogen in the leaves. Leaves should contain between 1.4 and 1.8 percent potassium. Below 1 percent leaf potassium, tree growth is compromised. Older leaves are affected first and develop a water soaked appearance and finally brown or scorched tissue appears. Also below 1 percent leaf potassium, height of trees, length of branches and trunk diameters are reduced.

Leaves may be free of visible symptoms with one percent potassium in the leaves but fruit may not colour properly. There will not be a colour response in the fruit if potassium levels are adequate. If this is the situation fruit colour will be impacted to a greater degree by decreasing Nitrogen than by increasing Potassium.

Where leaf analysis indicates low potassium levels, trees will require more potassium as yield increases. Leaf contents of 1.4 to 1.8% potassium indicates sufficient potassium while levels lower than 1.2% may be limiting. Young trees and non-cropping trees generally have higher leaf potassium than cropping trees. Therefore, levels of 1.4% may be adequate in cropping trees, but indicate low levels in non-cropping trees. The level of potassium (K) that is best for fruit quality depends on nitrogen (N) levels. Information from other areas indicates for varieties like McIntosh leaf ratios of 1 to 1.25 parts N to 1 part K may be desirable. For varieties like Red Delicious ratios of 1.25 to 1.5 parts N to 1 part K may be desirable. Leaf potassium levels should not exceed these suggested ratios and should lean to the low side, e.g. for Macs to 1.25 parts N to 1 part K, and Reds 1.5 parts N to 1 part K.

Potassium and Irrigation:

Soluble forms of potassium are moved relatively easily with irrigation water and leached as well but not as readily as nitrogen. Scheduling of irrigation while maintaining an adequate solution concentration tends to retain potassium in the root zone for uptake and reduces leaching.
When required it is recommended that potassium be applied in the major stress period of July and August at approximately 15 to 25 grams per tree in fixed irrigation cycles and between 10 and 15 ppm in scheduled Irrigation. Potassium requirements increase after the June drop, the amounts increasing according to the crop load. Potassium is critical in plant-water relations and once the cell division stage is passed, it is important to maintain good plant-water relations as cells and fruit enlarge. This is true particularly under the low humidity and heat stress of late July and August to ensure good fruit size.

There are some concerns about antagonisms that affect certain nutrients and that fruit quality may be affected. Research has indicated that in some years calcium is lower in the fruit with potassium fertigation but it did not fall below critical levels. It should be noted that this work was conducted with no fruit calcium sprays. Low calcium can be rectified with calcium sprays according to the Tree Fruit Production Guide.

Potassium Fertigation rates for Scheduled Irrigation*:

Tree age	crop load (bins)	ppm concentration of Potassium **
1	0	10
2	5	10
3	15	10
4	25	10
5	30	10
6	40	12
Older than 6	50	14

***To calculate parts per million K see scheduled irrigation fertigation calculation**
**** As tree size and crop load increase the trees will take up more water and more potassium meeting tree requirements.**

Note: The ppm K rates in this table are fertigated for 8 weeks for two hours per day with one 4 litre emitter per tree. For an irrigating period of one hour per day the rates would be doubled for example, 10 ppm would be increased to 20 ppm, and if irrigating and fertigating for one hour per day for only 4 weeks the rate would be 40 ppm of K.

Note: Fertigation with potassium should not start until July If this time frame overlaps with nitrogen application, $KN0_3$ can be used to supply both nutrients without negatively affecting soil pH. Calcium sprays are also applied during the July, August time frame.

Potassium Fertigation rates for Fixed Irrigation:

Tree age	Crop Load	gms/tree/week	gms K_20/tree/season*
1	0	2.5	20
2	5	2.5	20
3	15	2.5	20
4	25	2.5	20
5	30	3	24
6	40	4	32
Over 6	50	5	40

*Amounts per tree are based on a 0.9 m by 3m (3 ft x 10 ft) spacing, approximately 3700 trees per hectare or 1500 trees per acre. For a 0.6m by 3 m spacing (2 ft x 10 ft) these rates should be adjusted to 2/3 of the rate for the 1 m by 3 m spacing.

Note: for Bitter pit prone varieties do not apply potassium for crops 25 bins or less per acre

CALCIUM:

Calcium is one of the most important nutrients determining fruit quality. A major key to good fruit calcium levels is the vegetative fruiting balance in the tree. An important aspect of the movement of calcium is that when shoot growth is strong in the summer, calcium bypasses the fruit and is transported to the growing shoots. This limits calcium accumulation in the fruit to the period before rapid shoot growth. Therefore shoot growth needs to be controlled to improve calcium accumulation into the fruit. If leaf analysis indicates leaf levels of calcium greater than 1.8 percent the uptake of calcium has essentially been continuous through the season. In such a case it is highly likely that the fruit also received sufficient levels of calcium. In apples calcium uptake requires considerable quantities of photosynthates from the leaves. If photosynthesis is impaired from damage or stress from poor moisture levels, leaves shut down and calcium uptake is greatly impaired. The end result of low fruit calcium is a very high respiration rate and a high respiration rate decreases storability.

Factors affecting Calcium uptake:

Additional factors can affect calcium absorption. The presence of ammonium ions in the root zone will decrease the calcium absorption. Magnesium ions also exert an effect. When amounts of calcium are low in the soil solution the presence of magnesium will enhance uptake of calcium. If calcium levels in the soil are adequate, additional magnesium will negatively affect calcium uptake.
Calcium products may also be used in fertigation (without phosphorus products) but may only be useful to the tree under acid soil pH conditions. (It is often hard to increase fruit calcium through the soil)

BATCH MIXING INSTRUCTIONS (see sections and tables on types of materials, solubilities etc.,)

CALCIUM - ** Calcium products cannot be mixed with fertilizers that contain phosphorus and must be fertigated separately.

NITROGEN FORMS –Generally, calcium nitrate is a preferred form of nitrogen when pH decline is a concern. It is more readily absorbed and used by the tree in cool soils and does not acidify the soil. Although the tree will actually absorb NH_4 as well, ammonium and urea forms of nitrogen are changed in the soil to the nitrate forms to be used by the plant. This takes place as the soil temperatures increase.

SOIL pH –Under high pH conditions, acid forms of nitrogen, i.e. ammonium nitrate (34-0-0), ammonium sulphate (21-0-0), and urea (46-0-0) can be used. Calcium nitrate (15.5-0-0), which is not acidic, can also be used. Calcium is best applied as a foliar application for it to be useful for fruit quality**. NOTE: In addition, calcium fertilizers and magnesium sulphate (Epsom salts) cannot be mixed with phosphorus fertilizers.** Under high soil pH, ammonium nitrate (34-0-0) may be more useful because: (1) it can be mixed with phosphorus products, and (2) ½ of the 34-0-0 or 17% of the nitrogen is in the nitrate form.

SAMPLE CALCULATIONS:

Fertilizer calculation for Scheduled Irrigation:

To achieve a specific parts per million of fertilizer whether it is N, P, or K, the amount of fertilizer to be added to a mixing barrel has to be determined. In order to do this refer to the suggested parts per million in the sections for scheduled irrigation for the various nutrients. First determine the flow rate of water for a zone, (for example, if there are 1500 trees in the block or irrigation zone and there is one emitter per tree each with a flow rate of 4 l per hour, the total flow is 4 times 1500 or 6000 liters per hour). Next determine the injection rate of the fertilizer being injected into your irrigation lines. For mazzei injectors test the injection or suction rate by timing the suction out of a ten or twenty litre container to arrive at the number of ml injected per minute. This example shows 1000 ml minute, (the formula requires that this be expressed as millilitres per minute). A pressure compensating emitter can be attached to the end of the mazzei suction tube to reduce suction rates so the mix lasts longer.
The following formula is used to determine the number of kilograms of formulated fertilizer to add to a mixing barrel: **(please note that the nutrients for use in the scheduled fertigation calculation are expressed in ppm of the actual nutrient for example, ppm N, ppm P, and ppm K. The adjustment is made in the formula to allow for the fact that phosphorus is expressed as P_2O_5 on the bag, and potassium is expressed as K_2O on the bag.)**

Calculation for Dry granular soluble fertilizers:

C_1 = the target concentration in parts per million x nutrient content in fertilizer (**f**)

C_2 = the amount of fertilizer to be added to a mixing barrel in Kilograms/litre

Q_1 = the system flow rate in liters per hour (the rate of flow of each emitter, times the number of emitters in the irrigation zone)

Q_2 = the injection rate (ml per minute)

$$C_2 = \frac{C_1 \times f \times Q1}{Q2 \times 60{,}000}$$

<u>For Nitrogen:</u> (ppm N) (eg. 15.5-0-0; f = 100/15.5)

For example **C_2** $= \dfrac{50 \text{ ppm nitrogen} \times (100/15.5) \times 6000 \text{ l/hr}}{1000 \text{ml/min} \times 60{,}000}$

C_2 = 0.32 kg of 15.5-0-0/litre x the volume of mix tank
= 0.32 kg/l x 200 litre tank
= 6.4 kg /200 litre tank

<u>For Potassium</u>: (ppm K) (eg. 0-0-60; f = 100/60 x 1.21)

$$C2(kg/l) = \frac{C_1 \times f \times Q1}{Q2 \times 60{,}000}$$

$$C2\ (kg/l) = \frac{C1 \times (100/60 \times 1.21) \times Q1}{Q2 \times 60{,}000}$$

Answer in Kg/l therefore multiply by the volume of mix tank in litres

= Kg of 0-0-60 in tank

<u>For Phosphorus</u>: (ppm P) (eg. 10-52-0; f = 100/52 x 2.29)

$$C2(kg/l) = \frac{C_1 \times f \times Q1}{Q2 \times 60{,}000}$$

$$C2(kg/l) = \frac{C1 \times (100/52 \times 2.29) \times Q1}{Q2 \times 60{,}000}$$

Answer in kg/l therefore multiply by the volume of mix tank in litres

= Kg of 10-52-0 in tank

<u>Calculation for liquid fertilizers:</u>

<u>Note:</u> For liquid fertilizers such as 10-34-0, you need to consider the density of the liquid (1370 gm/l) to convert from kg to litres of fertilizer per litre in fertigation mix tank.

<u>For Phosphorus</u>: (ppm P) (10-34-0; f= 100/34 x2.29)

$$C2(L/L) = \frac{C_1 \times f \times Q1 \times 1000}{Q2 \times 60{,}000 \times \text{density}}$$

$$C2\ (L/L) = \frac{C1 \times (100/34 \times 2.29) \times Q1 \times 1000}{Q2 \times 60{,}000 \times 1370}$$

Answer in litres of 10-34-0 per litre of water therefore multiply the answer by the volume of mix tank in litres
= Litres of 10-34-0 in tank

Fertilizer Calculation for Fixed Irrigation Cycles:

Example # 1

This example calculates the amount of calcium nitrate (15.5-0-0) required by two- year old trees for a fixed irrigation (see nitrogen section for fixed irrigation cycles). This section recommends that 40 grams of nitrogen be applied per season for coarse soils. The first period of fertigation is from the start of rapid shoot growth. The amount suggested for two weeks is 6 grams or 3 grams for one week at the start of the fertigating period.

- Need to know the amount of nitrogen for one week or fertigating period
- Need to know the number of trees per irrigation zone or block
- Need to know the percentage of nitrogen on the fertilizer bag

Tz = the number of trees per irrigation zone or block (eg. 1500 trees)

Gnut = grams of nutrient, the number of grams of nutrient/tree/week or fertigating period handled by one tank of fertilizer mix (eg., 3 grams/tree/week)

X = percent of nitrogen content (15.5 % in $CaN0_3$ or 15.5-0-0)

C = amount of 15.5-0-0 to put in the mix tank for the fertigating period.

Formula:

$$C = \frac{Tz \times Gnut}{1\ \text{batch} \times X}$$

$$C = \frac{1500\ \text{trees/zone} \times 3\ \text{gms N}}{1\ \text{batch} \times 15.5/100}$$

$$C = \frac{1500 \times 3}{1 \times 0.155}$$

C = 29032 grams or 29 Kilograms of 15.5-0-0 (Calcium Nitrate)

.

Example # 2

This example calculates the number of litres of liquid 10-34-0 (ammonium polyphosphate) that is required to supply 58 grams of P_2O_5 for the planting year for a fixed irrigation cycle. (See the phosphorus section for fixed irrigation) Research at P.A.R.C. has shown that the amount of phosphorus required can be applied in one to several doses in the week or two before starting nitrogen fertigation on newly planted trees. Note – growers may wish to apply over one to two weeks so not too much water is required at any one time and the trees do not get over-watered.

Tz = the number of trees per irrigation zone or block (eg. 1500 trees/zone)

Gnut = the number of grams of P2O5 required per tree (58 grams of P2O5)

D = density of the liquid fertilizer (for liquid 10-34-0 it is 1370 gms/l)

X = percent P2O5 content of the fertilizer liquid

Cl = the number of litres of liquid material to put in the mix tank for the fertigating period

Formula:

$$Cl = \frac{Tz \times Gnut}{1\ batch \times D \times X}$$

$$Cl = \frac{1500\ trees/zone \times 58\ gms\ P2O5/tree}{1\ batch \times 1370\ gms/l \times 34/100}$$

$$Cl = \frac{1500 \times 58}{1 \times 1370 \times 0.34}$$

Litres of 10-34-0 = **186 litres**

Example # 2 – continued – In addition to the phosphorus supplied in the 10-34-0, 10 percent of the 186 litres was a number of grams of nitrogen. This amount of nitrogen will supplement the amount to be applied later, but due to losses etc., and the low conversion rate to nitrate at that time of year, the amount of calcium nitrate to be used in the first two weeks after the start of shoot growth could be reduced by half and later full recommended amounts could be fertigated.

Amount of Nitrogen in 186 litres of 10-34-0:

Tz = 1500 trees/zone
Tnut = unknown grams of N per tree
D = Density of liquid 10-34-0 (1370 gms/l)
X = percent of N in 10-34-0
Cl = 186 litres of 10-34-0 (previously calculated)

$$Cl = \frac{Tz \times Tnut}{1\ batch \times D \times X}$$

$$186\ litres = \frac{1500\ trees/zone \times Tnut}{1\ batch \times 1370gms/l \times 10/100}$$

$$\frac{1370 \times 0.10 \times 186}{1500} = Tnut$$

= **17 grams of nitrogen per tree in the 186 litres of 10-34-0**

Example # 3

This example deals with calculating the amount of potassium required. Potassium is expressed on the bag of fertilizer in terms of percent K20. For example potassium chloride is 0-0-60, this is 60 percent potassium as K20. As stated earlier in the section on potassium it is applied during times of stress in July and August. The section on potassium recommends 20 grams of K20 for the season for newly planted trees and for trees up to 25 bins of apples per acre, or 2.5 grams per week.

Tz = 1500 trees/irrigation zone or block

Tnut = 2.5 grams K20/tree/week

X = percent of K20 content of fertilizer of potassium chloride 0-0-60, 60 percent K20

C = Amount of 0-0-60 to put in mix tank for the fertigating period

$$C = \frac{Tz \times Tnut}{1 \text{ batch} \times X}$$

$$C = \frac{1500 \text{ trees/zone} \times 2.5 \text{ gms K20/tree}}{1 \text{ batch} \times 60/100}$$

$$C = \frac{1500 \times 2.5 \text{ gms}}{1 \times 0.60}$$

C = **6250 grams K20 or 6.2 Kg of 0-0-60**

FERTILIZER INJECTION PROCEDURES

(Please see British Columbia Trickle Irrigation Manual for more details)

To avoid burning roots, **the concentration of the solution coming out of the emitters should be 1-5% or less.** You can determine this by knowing the volumes of water per hour in the system and the volume of fertilizer mix being injected.
For example: With a Mazzei model 384 venturi pick-up, an injector inlet pressure of 100 psi, and an outlet pressure of 60 psi (the outlet side of your pressure reducing valve), the liquid suction rate is 8.2 US gallons per hour (31 litres per hour) (from Mazzei injector performance table, available at your irrigation dealer) Despite this, it is always wise to perform a "real suction test". A 10 or 20 litre pail can be used. Fill it with mix and start irrigating. Turn on the injector and allow the pail to be emptied and calculate how many litres per minute and per hour are suctioned. Use this figure.

You now need to know the volume of mix you are going to use and the volume of water used by the zone in one hour.

Volume of mix: the solubility values shown in Table 1 should not be used "as is" for injection into a trickle irrigation system. **Rather than using the value as gms/100ml of water it is suggested that water volume be increased 10 fold, using the same value but dissolved in a litre of water instead of 100 ml.** For example, 34-0-0 has a solubility of about 187 gm/100 ml at 20 degrees Celsius water temperature, and becomes gms/1000 ml or 187 gms/litre. (1.86 lbs per imperial gallon, or 1.55 lb per US gallon)

Volume of water in irrigation zone: volume of water in the irrigation lines depends on the volume of water used by the zone in an hour (this depends on the rate of flow of the emitters per hour and the number of emitters in the zone. If there were 1500 emitters per zone at a flow rate of 4 litres per hour the flow is 6000 litres per hour.

Now know the numbers to determine the concentration % the plants are receiving:

-Suction or injection rate in this example is 31l/hr
-Flow rate of water in the zone is 6000 l/hr

$$\frac{\text{Volume of concentrated mix /hr}}{\text{irrigation water flowing in system/hr}} = \frac{31\text{l/h} \times 100}{6000 \text{ l/hr}} = 0.5\ \%$$

The rate of feeding a concentrated fertilizer solution into the irrigation water should not be more than 1-5% of the rate of water flow, so this example value of 0.5% is good.

INJECTION:

Fixed Irrigation Cycles:

The irrigation lines must be filled or charged before injection begins. This will take 5 to ten minutes but will depend on the size of main lines, the length and the size of the zone. When injection is complete approximately one half hour of continued irrigation is required to ensure uniform distribution of the fertilizer. Experience has shown that when irrigation cycles are considerable longer than the injection period, the injection should start later in the irrigation cycle, to allow sufficient clearing time. This also reduces the amount of leaching of fertilizer.

Scheduled Irrigation:

Scheduled irrigation with fertigation still requires that lines be filled before injection. Since fertigation takes place during the whole irrigation period there is no clearing time required.

Note: In each of these cases, use the calculations in the batch mixing section to determine how many kilograms of fertilizer is required for a specific ppm for scheduled irrigation, or how many kilograms are required for fixed cycles based on the number of grams required per tree.

Injection time $= \frac{\text{volume of solution}}{\text{injection rate}}$

E.g. volume of solution = 200 litres

Injection rate: a figure from an injection chart available with the injector (this should be checked as outlined under injection procedures). With an inlet pressure of 100 psi and an outlet pressure of 60 psi using model 484 Mazzei injector, the suction rate (injection rate) is, 31 l/hr or (8.2 gal US/hour).

Therefore: injection time $= \frac{200 \text{ litres}}{3\text{l/hr}}$

$= 6.4$ hours

* For more details, see The B.C. Trickle Irrigation Manual **EQUIPMENT:**

Backflow prevention:
A backflow prevention device is required to be placed in line upstream from any injection equipment.

Injection methods:

Trickle irrigation systems can utilize a number of different injection methods.
The main types used are venturis, ratio feeders, and electric or water driven injector pumps. The factors that affect which type to use include cost, available power, reliability, the chemical to be injected, number of chemicals to be injected simultaneously and the ease of regulating the injection rate.

Venturi injectors – require at least a 20% pressure drop between the inlet to the Venturi (prior to a pressure reducing valve) and the outlet from the Venturi. Some growers have noted difficulty in injecting the amounts of liquid per minute that charts specify. The Venturi unit must be sized for your system. If there are too few emitters to create enough flow, too much of the flow has to go through the venturi and the pressure differential is reduced and the required suction will not take place. If the pressure differential is too low there may be no suction at all. If the flow is too low for the smallest Venturi device, you will have to use a different injection system. (Please see fig. 1 for a diagram of a Venturi Injector set-up).

Ratio Feeders: (for example, Dosatron Ratio injector).

Ratio feeders are a water- driven type of injector pump. The quantity of material injected will depend on the flow rate through the injector but the concentration of chemical in the irrigation water will remain the same. Therefore if the injector is set at a ratio of 1%, a zone flow rate of 100 gpm will have an injection rate of 1gpm. A zone flow rate of 50 gpm will have an injection rate of 0.50 gpm. Ratio feeders generally operate at injection ratios of 0.2% to 2%.

Since the proportion of chemical injected does not vary with the system flow rate or operating pressure, these types of injectors can be used in situations where the system automatically can change from one zone to another providing the concentration required in each zone is the same. (Please see figure 1 for a diagram of Ratio Feeder set-up).
Venturi and ratio feeders are usually installed on a bypass line that runs parallel to the main irrigation line.

Timers: Some growers have experienced problems with power surges and/or strikes from lightening. A basic surge suppressor or power bar used for plugging in computers will eliminate surges or spikes in voltage when power lines are struck in the vicinity. If the surge is too great it may fry the metal oxide rectifiers in the power bar and still affect your clock. The bar will then be acting as an ordinary outlet and will not suppress surges and the rectifiers will need replacing.

Grounding: Your clock must be properly grounded. If it is connected to your house system with a proper ground it should be fine, but if the clock is out in the field it must still be grounded properly. Use an eight-foot grounding rod and it must be placed no further than 12 feet from your clock. * It is wise to check with an irrigation company that is familiar with proper lightening and surge protection equipment.

Other methods are:

- Orchard sprayer pump
- Electric metering pump
- Bypass feed tank
- Feed line into pump suction side (for systems which use a pumped water supply)

COMPATABILITY CHART

Solubilities:

It is very difficult to generalize because solubility depends on a number of factors, the most important being pH, the concentrations of the solutions and solution temperature. Any concentration of more than two products will have reduced solubility over two materials alone. This chart is only a guide, and where you may have questions do a trial mix in a bucket using representative amounts of material and water.

	Urea	Ammonium nitrate	Ammonium sulfate	Calcium nitrate	Potassium nitrate	Potassium chloride	Potassium sulfate	Ammonium phosphate	Fe, Zn, Cu, Mn chelate	Fe, Zn, Cu, Mn sulfate	Magnesium sulfate	Phosphoric acid	Sulfuric acid	Nitric acid
Urea														
Ammonium nitrate														
Ammonium sulfate														
Calcium nitrate			■											
Potassium nitrate														
Potassium chloride														
Potassium sulfate			▨	■		▨								
Ammonium phosphate				■										
Fe, Zn, Cu, Mn sulfate				■			▨	■						
Fe, Zn, Cu, Mn chelate				▨				▨						
Magnesium sulfate				■			▨	■						
Phosphoric acid				■						▨				
Sulfuric acid				■			▨							
Nitric acid										■				

■ - Incompatible

▨ - Reduced solubility

☐ - Fully compatible

Certain chemicals that are used for formulating custom liquid fertilizers are incompatible in the concentrated fertilizer stock solutions. This compatibility chart illustrates some of the chemical combinations that should be avoided in the same stock solution (modified from Soil and Plant Laboratory Inc., Bellevue, WA)

MATERIALS:

(Please see British Columbia Trickle Irrigation Manual for more details.)

There is a range of materials available. (Please see Table 1 - B.C. Trickle Irrigation Manual)

The following is a list of some of the soluble granulars that contain Nitrogen, P as P205, and K as K20.

FULL NUTRIENT PREMIX WATER SOLUBLE GRANULAR MATERIALS

Materials*

(N P*K* - *P as P_20_5, *K as K_20)

0-52-10 + micronutrients
(0.9% NO3) - (7.8% NH_4) – (1.3% Urea)

15-30-15 + micronutrients
(4.4% NO3) - (5.9% NH_4) – (4.7% Urea)

20-20-20 + micronutrients
(5.9% NO3) - (3.85% NH_4) – (10.25% Urea)

20-8-20 + micronutrients
(5% NO3) - (4% NH_4) – (11% Urea)

28-14-14 + micronutrients
(4.1% NO3) - (2.75% NH_4) – (21.14% Urea)

18-9-27 + micronutrients
(8% NO3) - (4% NH_4) – (6% water soluble organic N)

15-15-30 + micronutrients
(8.8% NO3) - (2.95% NH_4) – (3.25% Urea)

* Other soluble granular materials are available – check with dealer for % nitrate, % ammonium and % urea.

*** NITROGEN**: Most granular forms of N are readily soluble in water and can be used for fertigation purposes.

Type		Solubility**
Urea	46-0-0	108 gm/ml (at 20 degrees C)
Ammonium Nitrate	34-0-0	187 gm/ml (at 20 degrees C)
Calcium Nitrate	15.5-0-0	250 gm/ml (at 20 degrees C) (22.7 kg bag)

** These solubilities are under ideal laboratory conditions. It may be very difficult to dissolve the amounts suggested in the amounts of water suggested in the field. So it is suggested to use these figures in one litre of water, for practical field use (for example ammonium nitrate would be 187 gms/litre)

Later in the season (July) calcium and potassium nitrate forms are also useful as they allow nitrogen to be quickly used and do not linger in the soil to encourage late season growth and negatively affect fruit colour and winter hardiness.

PHOSPHORUS: Not all forms are acceptable, for example treble super-phosphate 0-45-0 changes spontaneously to dicalcium phosphate and precipitates if any calcium is present in the water. The precipitates clog lines and emitters.

Acceptable forms are: the entire full nutrient premixed water-soluble granular materials previously mentioned, which contained phosphorus. But also below:

Materials	**Weight**
(Liquid materials)	
* Phosphoric acid - (0-54-0) - Density 1574 gm/litre	35 kg
10-34-0 10% nitrogen is ammonium form Density 1370 gm/litre	200 L
(Water-soluble granular materials)	
21-53-0 diammonium phosphate	25 kg
0-52-34 mono-potassium phosphate	25 kg
12-62-0 mono-ammonium phosphate	50 kg

* Phosphoric acid:

The label will say 75% phosphoric acid (H_3PO_4). For the purpose of calculations for fertigating for fixed irrigation cycles we need to know the % phosphorus as P_2O_5.(for scheduled irrigation phosphorus is expressed as ppm of actual phosphorus, and is accounted for in the calculation)

Multiply 75% x conversion factor of 0.72. Therefore % P_2O_5 is 54%, so the product in fertilizer terms is 0-54-0.

Note: you need the density of 1574 gm/litre when doing calculations (see examples).

Precipitate problems can occur even with these forms of phosphorus, particularly with water high in calcium or magnesium (above 300 ppm) or when mixing fertilizer. *A mixing test should be done if water analysis shows calcium and magnesium are above 300 ppm.

*Fertilizer formulations such as ammonium polyphosphate (10-34-0) or phosphoric acid (0-54-0) can be used without forming precipitates. A test to determine whether precipitation will occur should be done by mixing the fertilizer solution with a sample of irrigation water in the same proportions, as they would be if injected into the irrigation line. This problem can occur particularly if the water is high in calcium, magnesium, or if phosphorus is being injected at the same time as certain other types of fertilizers, particularly calcium nitrate, or even if calcium or magnesium is immediately followed by phosphorus. Leave a clearing period to avoid this problem.

POTASSIUM: The entire full nutrient premixed water soluble materials previously mentioned. Also the following:

Materials		Weight
(Water-soluble granular materials)		
* 0-0-50	potassium sulphate	22.7 kg
*** 13-0-46	potassium nitrate	
** 0-0-60	muriate of potash (potassium chloride)	25 kg
*** 12-0-44	potassium nitrate (12% nitrate nitrogen)	15 kg
*** 0-52-34	mono-potassium phosphate	25 kg

* Potassium sulphate: is not very soluble; the Trona brand potassium is the most soluble of potassium sulphate products. There is also a fine grade K-Mag (potassium magnesium sulphate) fertilizer that is currently being tested for fertigation. It is especially suitable if low magnesium is a problem.

** Has a relatively high salt index and may cause excessive salt build-up, especially in potted situations.

*** Are the preferred materials.

MICRONUTRIENTS:

Chelates or sulphates of most minor elements can be safely applied, but they may be more efficiently applied as foliar sprays.

CALCIUM:

Materials	
15.5-0-0	calcium nitrate*

* Calcium nitrate can be applied through the drip system, but may only be effective under acid soil conditions (below pH7). Foliar applications generally are the most effective application method (see later comments on calcium). Calcium for pH correction – see the Tree Fruit Production Guide for details.

Table 1	Granular Fertilizer Properties				
Fertilizer	**Molecular**	**%Element**	**Solubility**	**Temp**	**Equivalent ***
	Compound		**g/ 100 ml**	**deg C**	**CaCO3**
Ammonia	NH_3	82% N	90	0	148
Ammonium Nitrate	NH_4NO_3	34% N	118	0	62
			187	20	
			590	80	
Ammonium Sulphate	$(NH_4)2SO_4$	21% N	71	0	110
		24% S	95	80	
Calcium Carbonate	$CaCO_3$		0.006	0	
Calcium Metaphosphate	$Ca(PO_3)$		0.001	0	
Calcium Nitrate	$Ca(NO_3)2 . 4H_2O$	15.5% N	134	0	-20
			364	100	
Calcium Sulphate	$CaSO_4. 2H_2O$		0.24	0	
Copper Sulphate	$CuSO_4.5H_20$		32	0	
Diammonium Phosphate	$(NH_4)2HPO_4$	18% N	25	0	70
		20% P			
Dicalium Phosphate	$CaHPO_4.2H_2O$		0.02	0	
Magnesia	MgO		0.0006	0	
Magnesium Sulphate	$MgSO_4.7H_2O$		85	0	
Manganese Sulphate	$MnSO_4.4H_2O$		105	0	
Monoammonium Phosphate	NH_4H2PO_4	11% N	43	0	58
		22% P			
Monocalcium Phosphate	$CaH_4(PO_4)2 H_2O$	20% P	varies		
Potassium Chloride	KCl	60% K_2O	28	0	neutral
			51	80	
Potassium Nitrate	KNO_3	13% N	13	0	-26
		46% K	169	80	
Potassium Sulphate	$K2SO_4$	53% K_2O	8	0	neutral
Sodium Nitrate	$NaNO_3$	16% N	73	0	-29
Urea	$CO(NH_2)2$	46% N	67	0	71
			108	20	
			167	40	
Zinc Sulphate	$ZnSO_4. 6H_2O$		70	0	

Adapted from B.C. Trickle Irrigation Manual

*Equivalent $CaCO_3$ - kg of $CaCO_3$ per 100kg of fertilizer to neutralize

Table 2

Fertilizer Solutions		
Fertilizer Solution	% Nutrient	Density
		Grams /liter
	Nitrogen	
Urea Solution	23% N	1140
Urea Solution	20% N	1120
Ammonium Nitrate	20% N	1270
N Solution	30% N	1270
Urea Ammonium Nitrate	28% N	1280
Urea Ammonium Nitrate	32% N	1330
Ammonium Nitrate Ammonia	37%	1190
Ammonium Nitrate Ammonia	41% N	1140
Calcium Ammonium Nitrate	17% N	
Aqua Ammonia	20% N	910
Aqua Ammonia	24%	900
	Phosphorus	
Phosphoric Acid	52% P_2O_5	
	68% P_2O_5	
	75% P_2O_5	1574
Ammonium PolyPhospate	8% N	1260
	24% P_2O_5	
Ammonium PolyPhosphate	9% N	1360
	30% P_2O_5	
Ammonium PolyPhosphate	10% N	1370
	34% P_2O_5	
Ammonium PolyPhosphate	11% N	1410
	37% P_2O_5	
	Potassium	
Potassium Ammonium	15% N	
phosphate	52% P_2O_5	
	10% K_2O	
Potassium Ammonium	10% N	
Phosphate	10% P_2O_5	
	10% K_2O	
Potassium Ammonium	15% N	
Phosphate	8% P_2O_5	
	4% K_2O	

* B.C. Trickle Irrigation Manual

Table 3

Foliar Nutrition Program

Nutrient	Dormant	1/2 inch green	tight Cluster	Open clustr	Pink	Blossom	petal fall	end of flowering	fruit growth	harvest	Post Harvest
	zinc is chronically deficient and is critical for enzyme systems, fruit size and density and bud strength for next year										
			*	a minimum of one spray pre pink and one post harvest							
Zinc	**# 1**										
	Zinc Sulphate-spray at 16 kg per acre or 38.5 L/acre										
	Note: Do not apply below 4 deg C or if temp will fall below freezing before dry										
		#1	**#1**								**#2**
		Foliar Zinc products @ recommended rates									
Warning	**Do not apply after fruit set as zinc may russet**										
Boron				**#1**	**#1**						**#2**
				Foliar Boron products @ recommended rates							
	Boron is essential for fruit set and pollen tube growth and longevity of flower ovule										
	Fall boron is more effective than Spring applied boron										
	Note: Boron should only be applied on the ground if soil and leaf test indicate low levels										
	High fruitlet levels will result in soft fruit and early maturity										
Nitrogen		#1		#2			# 3				#4
		urea - 2.4 to 3.2 kg per acre for sprays 1,2,3									
		Post harvest spray # 4 apply 5 to 10 kg urea per acre 1 to 3 times									
		Soluble Boron products to be applied @ recommended rates									
		The Fall post harvest schedule has a major effect on flower strength, fruit set and fruit size the next year Strongly recommend post harvest urea as opposed to fall ground applications									
Magnesium					#1			#2	#3		
	Specially formulated magnesium products @ rec rates							for sprays # 1 & # 2			
					or **epsom salts** - 3 kg/A for spray # 1, #2 & #3 apply at 7 kg to 8 kg per acre						
	Magnesium is essential for chlorophyll in the leaf and photosynthesis										
	Essential for Phosphorus metabolism, water uptake, protein sysnthesis, low levels increase Pre-harvest drop.										
	for deficiency apply at pink timing as well as caylx										

Nutrient	Dormant	1/2 inch green	tight Cluster	Open Cluster	Pink	Blossom	petal fall	end of flowering	fruit growth	harvest	Post Harvest

Phosphorus

#1

foliar phosphorus products

I application
may also contain
Calcium and Zinc

Urea

1- 2 kg

#2

foliar phosphorus products @ recommended rates
7 to 14 days apart(do not use products that contain
zinc post bloom)
(check levels - if low use more than one application)
generally compatible with Sevin thinning
some not compatible with
Thiodan

#3

#3 Preharvest foliar phosphorus products
2-4 weeks before harvest

Phosphorus -Phosphorus and Calcium help build strong cell walls to make firmer fruit that is less prone to storage disorders.

Calcium

#1

Calcium Nitrate 2 -3 Kg/A
do not apply after 1 inch fruit size
could negatively affect colour

Calcium sprays starting early, build strong
cell walls that greatly assists in reducing
Calcium related disorders such as
bitter pit internal browning etc.

#2

Caltrac - 1.2 L/A 4 or more sprays
up to 1 month B4 harvest, assists in
sunburn
reduction
Cor- clear (calcium chloride)
Low volume water 2.6 Kg/A
High volume water 3.8 Kg/A
do not apply calcium chloride products
in temps over 27 deg C.
see details for compatiblilty of calcium
chloride in Prod Guide

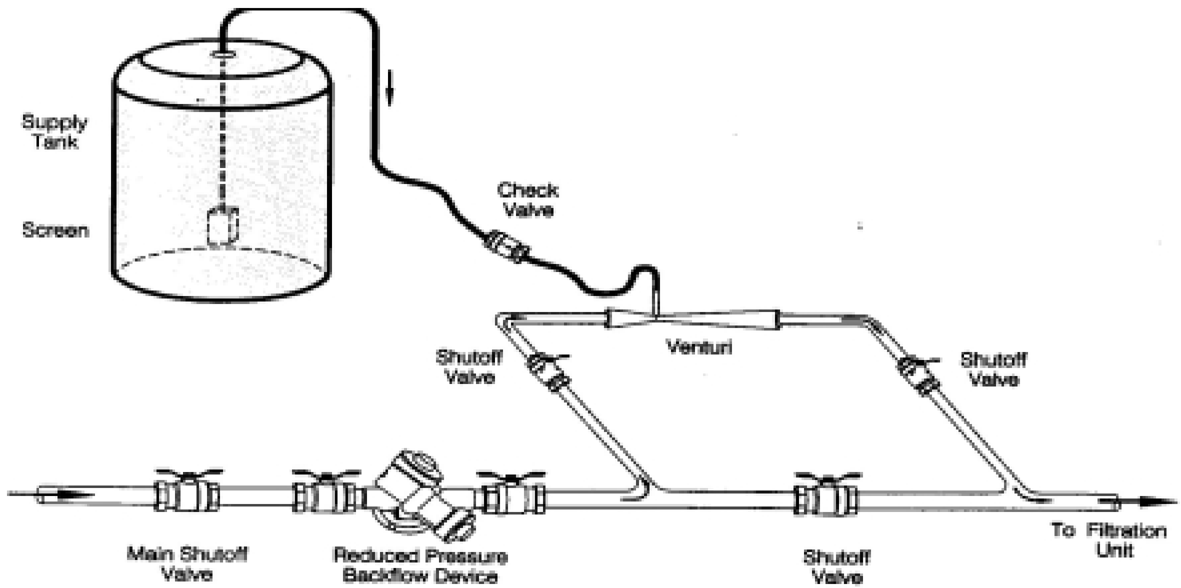
Potassium

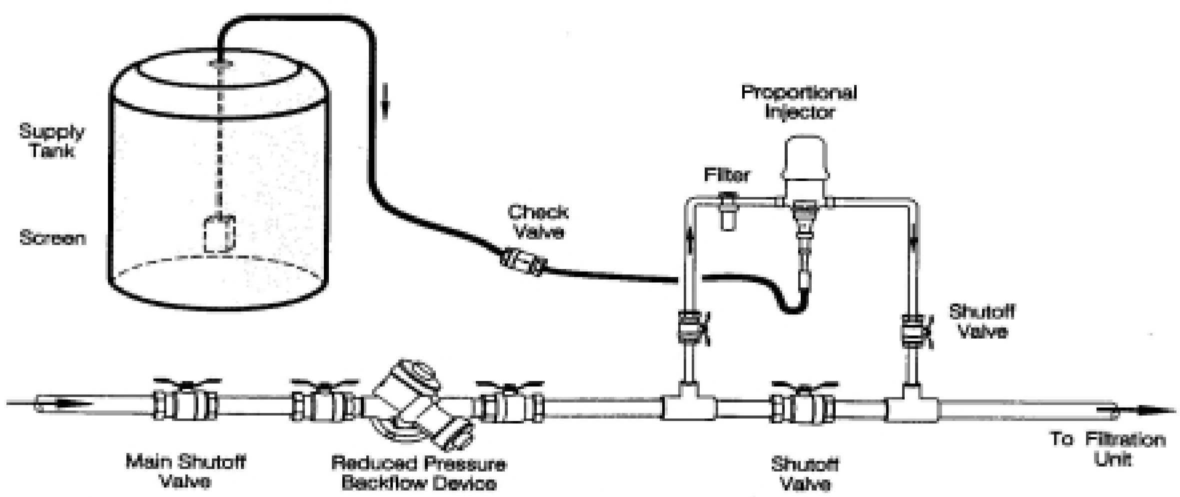
Determine leaf soil and fruit levels - Adequate levels assist in reducing tree stress to excessive heat and moisture stress. Low levels result in poor colour and size and leaf scorch. High levels of K affect Calcium levels and can negatively affect firmness and storability.

Potassium is readily taken up by tree so address soil levels - check leaf and fruitlet.

Formulated foliar potassium products- apply at bud burst and post harvest

Figure 1 – **Venturi & Ratio feeder installation**





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References:

Childers N.F., Temperate to Tropical Fruit Nutrition, 1966, Horticultural publications, Rutgers The State University

Faust M., Physiology of Temperate Zone Fruit Trees, pp 53- 168, John Wiley & Sons 1989

Neilsen D. and G.H. Neilsen, Effects of Irrigation Management on Nitrogen Availability In High Density Apple Orchards. Acta Hort 448. ISHS 1997

Neilsen G.H. and D. Neilsen, Orchard Nutrition To Maximize Crop Quality And Minimize Environmental Degradation, in Mineral Nutrition and Fertilizer Use for Deciduous Fruit Crops, Acta Hort. 448. ISHS 1997

Neilsen D. and G.H. Neilsen, Nitrogen and Water Management In High Density Apple Orchards, Presented at the Western Nutrient Management Conference, Salt lake City UT, March 8-9,2001

Neilsen G.H. and D. Neilsen, Potassium Sources for Fertigation Of Apples, (Research conducted 1992-1997 at P.A.R.C.)

Neilsen G.H., D. Neilsen, and F. Perya, Responses of Soil and Irrigated Fruit Trees to Fertigation or Broadcast Application of Nitrogen, Phosphorus and Potassium, Hort Technology July-September 1999

Neilsen D., G.H. Neilsen, L. Herbert, and G. Hogue, Nitrogen Management in High Density Apple Orchards, (Research conducted 1997-2000 at P.A.R.C.)

Neilsen G.H., D. Neilsen, L. Herbert, and G. Hogue, Response of "New" Apple Cultivars to Nutrition Treatments, (Research conducted at P.A.R.C. 1998-2000)

Neilsen D., P. Parchomchuk, G.H. Neilsen, and E.J. Hogue, Using Soil Solution Monitoring to Determine the Effects of Irrigation Management and Fertigation on Nitrogen Availability in High-Density Apple Orchards, J. Amer. Soc. Hort. Sci. 123(4): 706-713,1998

Neilsen G.H., P. Parchomchuk, D. Neilsen, R. Berard, and E.J. Hogue, Leaf Nutrition and Soil Nutrients are affected by Irrigation Frequency and Method for NP- Fertigated "Gala" Apple, J. Amer.Soc.Hort Sci. 120(6): 971-976. 1995

Neilsen G.H., P. Parchomchuk, D. Neilsen, And B.J. Zebarth, Drip-fertigation of Apple Trees Affects Root Distribution and Development of K Deficiency, PARC contribution No. 20943. February 2000

Neilsen G.H., P. Parchomchuk, R. Berard, and D. Neilsen, Irrigation Frequency and Quantity Affect Root and Top Growth of Fertigated "McIntosh" apple in M.9, M.26 and M7 Rootstock PARC contribution no. 977, August 1996

Neilsen D., P. Millard, G.H. Neilsen and E.J. Hogue, Sources of N for Leaf Growth in a High-Density Apple (Malus domestica) Orchard Irrigated with Ammonium Nitrate Solution, Tree Physiology 17,733-739

Neilsen D., P. Millard, G.H. Neilsen, and E.J. Hogue, Soil-Plant Water Relationships, Nitrogen Uptake, Efficiency of Use and Partitioning for Growth in Young Apple Trees, Amer. J. Hort. Science, 2001

Neilsen D., P. Millard, L.C. Herbert, G.H. Neilsen, E.J. Hogue, P. Parchomchuk, and B.J. Zebarth, Remobilization and Uptake of N by Newly Planted Apple Trees (Malus domestica) In Response to Irrigation Method and Timing of N Application, PARC contribution no. 2074, Tree Physiology 2001

Neilsen D., Paul B. Hoyt, P. Parchomchuk, G.H. Neilsen, and E.J. Hogue, Measurement of the Sensitivity of Orchard Soils to Acidification, PARC contribution no. 893 May 1995

Sanchez E.E., and H. Khemira, D. Sugar, T. L. Righetti, Nitrogen Management in Orchards, in "Nitrogen Fertilization in the Environment", Published by Marcel Dekker Inc 1995, pp 327-380

Stiles W.C., and W. Shaw Reid, Orchard Nutrition Management, Information Bulletin 219, Cornell Cooperative Extension

Waterman P., E.J. Hogue, H. Quamme, Tree Fruit Home Nurseries – A Growers Manual, published by the Okanagan Valley Tree Fruit Authority.

Van der Gulik T., "B.C. Trickle Irrigation Manual." 1999 published by the B.C. Ministry Of Agriculture and Food, and The Irrigation Industry Association of British Columbia.