CHAPTER 10

FERTIGATION SYSTEMS AND NUTRIENT SOLUTIONS

INTRODUCTION

*Plants can tolerate a wide range of watering and nutritional conditions…
However, for a commercial operation,
the bottom line is profit which means optimizing plant growth and yield.

*Optimum watering and mineral nutrition are critical for optimum plant growth.

*Optimum watering and nutritional conditions can vary
For different plant species
For the same plant species at different times of its life cycle
For the same plant species at different times of the year
For the same plant species under different environmental conditions

***This chapter describes**
Properties of the nutrient solution
The physical systems required to deliver the nutrient solution to the plants
How to calculate how much of each dry compound to use in the solution

DEFINITIONS

***Irrigation =** The supplying of water to plants using ditches, pipes, streams, etc.

***Fertilizer =** Inorganic "salts" containing the essential macro and micro elements necessary for plant growth (see Chapter 9). Also organic compounds that contain such elements (i.e., manure, fish emulsion, bat guano, etc.) that, when added to the soil or water, increase it's "fertility".

***Fertigation =** The **use of fertilizers** in the appropriate combination, concentration and pH, **for every irrigation cycle** (usually inorganic for commercial greenhouse hydroponics and smaller systems, though some hobbyists and even some commercial growers are now using organic mixtures).

***Nutrient solution recipe =** A list of inorganic compounds, and their final concentrations in **ppm** ("parts per million" or "milligram per liter") or mMol (millimole), etc. This can also include actual amounts of the compounds needed to achieve the prescribed concentrations, given specific tank volumes, dilution factors, etc. For organic mixes, the recipe will be a list of organic materials to use. Make sure that components are of consistent quality from batch to batch.

NUTRIENT DELIVERY SYSTEMS

***Simple systems:** (no pump needed to move the nutrient solution)

Non-recirculating air gap system or the raft system (see Chapter 5) where the roots hang down directly into the nutrient solution.

Basic wick system (see Chapter 5) in which the nutrient solution is drawn up by an absorbent wick into an aggregate where the roots grow.

***Complex systems:** (a pump is needed to move the nutrient solution)

The flood and drain, top feeder, NFT or Aeroponic systems (see Chapter 5) all of which require pumps to move the nutrient solution from a reservoir or series of tanks to the plants via PVC, poly and drip tubing, emitters, etc.

NUTRIENT SOLUTIONS

***The importance of good quantity/quality water for hydroponic plant production:**

Any hydroponic nutrient solution begins with the "source water".

A grower can obtain **source water** from

City water supply
Private wells
Water harvesting (channeling rain water into catchments)

*The **Source Water** - must have the appropriate **quantity and quality:**

***Quantity:** There must be sufficient water available for plants and for cooling.

Ex: For tomatoes in greenhouse hydroponics:

~4 liters/plant/day (Note: 3.785 liters = 1 gallon)
or if 2.5 plants/m^2, then 10 liters/m^2/day.

If evaporative cooling is used, especially in deserts, water needs may double!

***Quality:** Factors to consider include pH, EC (salt levels) and contaminants:

pH: The p(otential of) H(ydrogen): Acidic or basic character of the water.

$pH = -\log [H^+]$ (neg. log of the H^+ conc.) Scale = 0-14

Ex:
If $[H] = 10^{-7}$, then pH = 7 (Neutral, i.e. pure water)
If $[H] = 10^{-4}$, then pH = 4 (Acidic)
If $[H] = 10^{-9}$, then pH = 9 (Basic)

Ways to test the pH: Litmus paper (color change)
pH meter (analog or digital) - measures $[H^+]$

For most plants: pH 5 – 7. **For tomatoes: 5.8 – 6.5**

Above pH 7 or below pH 5: may cause problems with nutrient uptake into the roots or translocation within the plant resulting in deficiencies or toxicities.

EC (Electrical conductivity): a measure of how well a solution carries an electrical current and of the total salts (e.g., fertilizers) in that solution.
Pure water (no salts) EC = 0. The higher the salt levels, the higher the EC.
Example: EC of sea water = ~50 mS/cm (Note: 1 mS/cm = 640 ppm)
Unit = mS/cm (milli-Siemen / centimeter) or TDS (total dissolved solids)

For mature tomatoes: Drip EC = 2.5 – 3.5 mS/cm (drain ~1 unit higher)
Depends on environmental conditions, plant architecture desired, etc.:
High light/temp = Lower EC
Low light/temp = Higher EC
More vegetative = Lower EC
More reproductive = Higher EC

Elevated salt levels: Certain areas of the country/world have salts in the water (see Chapter 11-2 for maximum salt levels allowable in the source water).
High boron, fluoride, chloride, sulfates and sodium:
-Can cause poor plant growth.
-May influence soluble salt levels in the water.
High iron, especially in “hard water” (having high Ca and Mg):
-Can cause rusty spots on leaves with overhead irrigation.
High salt levels can also cause rapid salt buildup on cooling pads.
-May need to bleed off and replace pad water regularly.

Heavy metal contaminants:
Certain geographic areas have high levels in the soil and/or water.
High lead, cadmium, aluminum, silver, etc.:
-May be excluded or absorbed on a limited basis by plants.
-May be absorbed and stored (but not toxic to the plants).
Vegetables from CO mining areas contain high lead & cadmium!
-May be toxic to the plants.

The QUALITY of the water MUST BE ASSESSED by an ANALYSIS
Several labs across the country analyze source water, including:
CropKing OH 800-321-5211, www.cropking.com has a service with
Micro Macro (MMI Labs) GA, www.mmilabs.com
A & L Great Lakes Laboratories, Inc., IN, www.lagreatlakes.com
Clemson University, Agricultural Services Laboratory.
http://www.clemson.edu/public/regulatory/ag_svc_lab/services/greenhouses.html
Penn State Analytical Services Laboratory http:// http://agsci.psu.edu/aasl

***Mineral elements or nutrients:** 16 elements required for plant growth (see Chapter 9)
3 elements from air and/or water: C, O, H
13 elements from the soil/nutrient solution (that must be added via the solution):
Macros: N, P, K, Ca, Mg, S
Micros: B, Cl, Cu, Fe, Mn, Mo, Zn

The 13 essential mineral elements can be obtained from the following compounds:
$MgSO_4$*7 H_2O (Magnesium Sulfate)
KH_2PO_4 (Monopotassium Phosphate)
KNO_3 (Potassium Nitrate)
H_3BO_3 (Boric Acid)
$MnCl_2$*4H_2O (Manganous Chloride)
$CuCl_2$*2H_2O) (Cupric Chloride)

K_2SO_4 (Potassium Sulfate)	MoO_3 (Molybdenum trioxide)
$Ca(NO_3)_2$ (Calcium Nitrate)	$ZnSO_4*7H_2O$ (Zinc Sulfate)
	Fe 330 – Chelated iron (Sprint/Sequestrene)

More recently, some of the micronutrients have been harder to find and more expensive. This year (2016) we changed our nutrient formulation to use the following:

$MnSO_4$	(Manganese sulfate)	$Na_2MoO_4*2H_2O$ (Sodium molybdate)
$CuSO_4$	(Copper Sulfate)	

Then we need to add chloride using $CaCl_2$ (calcium chloride).

In solution these compounds dissociate into ionic forms (inc.'d charge = inc.'d EC):
Ex: $MgSO_4$ dissociates into the **cation** Mg^{++} and the **anion** $SO_4^{=}$
Ex: KNO_3 dissociates into the **cation** K^+ and the **anion** $NO3^-$
Ex: $CuCl_2*2H_2O$ dissociates into the **cation** Cu^{++}, the **anions** $2Cl^-$ plus 2 H_2O
NOTE: In a chemical equation the cations are listed first, then the anions.

***Nutrient interactions:**

Plants maintain a balance between the **cations** (positively charged ions) and **anions** (negatively charged ions) in their cells and tissues.

Plants also maintain a constant sum of **cations** in their cells and tissues.
Therefore, if one cation is increased, it may decrease the uptake of others.
Ex: Increasing Mg^{++} can cause decreases in Ca^{++} and calcium deficiencies.
Ex: Increasing $NH4^+$ (to increase acidity) can cause decreases in Ca^{++} uptake.

Interactions between **anions** are not as common.
Ex: Increasing Cl^- can decrease $NO3^-$ uptake and visa versa.

***Nutrient uptake rates and mobilities:**

Plant roots take up mineral nutrients at different rates.
Ex: NO_3^-, K^+ and Cl- are taken up quickly; Ca^{+2} and SO_4^{-2} are taken up slowly.
This results in unequal removal of nutrients from the solution.

Once in the plant, different ions have different mobilities within the plant.
- Mobile ions include N, K, P (PO_4^{-2}), Mg and Cl.
  - Deficiency symptoms for these ions usually appear in the old growth.
- Slightly mobile ions include S (SO_4^{-2}), Mn and Mo.
  - Deficiency symptoms usually appear in the middle and old growth.
- Immobile ions include Ca, B, Zn, Fe and Cu.
  - Deficiency symptoms for these ions usually appear in the new growth.

***Recommended nutrient levels (ppm) according to plant species (Agrodynamics):**

CROP	**N**	**P**	**K**	**Mg**	**Ca**
Tomatoes	200	50	360	45	185
Cucumbers	230	40	315	42	175
Peppers	175	39	235	28	150

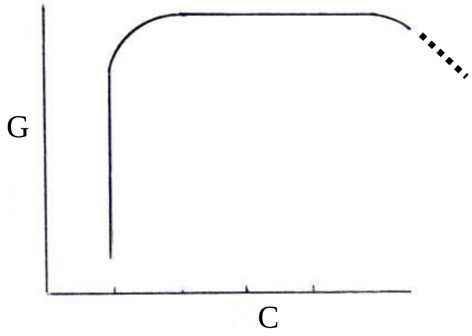
However, several crops can grow perfectly fine on the same nutrient solution.
Recipe with three crops (UA CEAC GH): N=189, P=39, K=341, Mg=48, Ca=170

***Plant growth as a function of nutrient concentration in plant tissue:**

Plant nutritionists, in the mid-1900's, discovered that there is a **critical nutrient concentration (C),** below which plant growth **(G)** is reduced or terminated.

Above the critical nutrient concentration is the **adequate zone** where growth is 100% of maximum.

At high nutrient concentrations, plant growth is again reduced. This is the **toxic zone.**



***Top-drip fertigation systems: Open (drain to waste) vs closed (recirculating)**

See diagram at end of chapter: Nutrient solution is pumped (pump or municipal water pressure) from the fertigator through 1/2inch poly tubing, through the drippers (inserted into the poly) and to the plants through drip tubing.

In an **open system** the nutrient solution is only used once on the crop plants.

In a **closed system** the nutrient solution is used then analyzed for pH and nutrients, adjusted to the proper levels using acid/base, water and/or nutrients, sterilized to control the spread of water-borne pathogens (can include UV, ozone or other treatments) and finally returned to the plants.

***Watering strategies and "rules of thumb".**

Which dripper/emitter to use?

"Smaller flow gives better control": 0.5 gallon/h (2 liter/h) is a good size.

Use "pressure compensated" emitter (gives "rated flow" with diff. press.)

Use 1 dripper per plant (or per head, i.e., 2 drippers/double-headed tomato plant)

Choose the "ON" time to give 60 - 120 ml of nutrient solution per watering.

[1st week, with small plants, deliver 40-50ml/watering, 6-8 times/day]

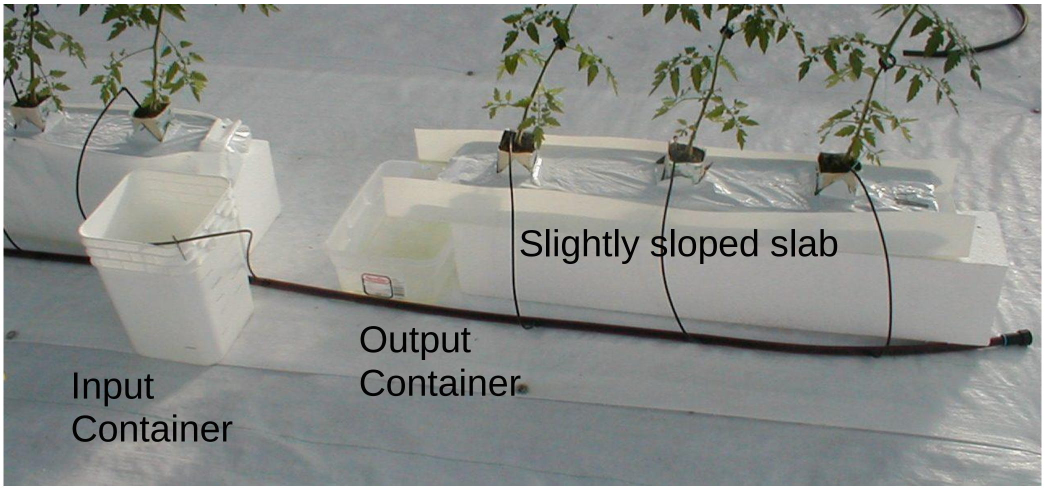
***How to measure input and output solution and how to calculate % output.**

Since fertigation adds fertilizer with every watering, <u>salts can build up in the slab</u>.

You want 15% to 30% of the input solution to drain out (flushes salts out).

If % output is less than 15% → not enough drainage: inc. # of irrigations.

If % output is greater than 30% → wasting solution: dec. # of irrigations.



See picture above: Add one extra dripper and place drip tube into a container. Elevate one slab (bag) and set it on a slight slope so that it drains into a tub. Every 24 hours empty both containers. Measure amounts (ml), pH and EC.

Calculate the % output from the measured amounts as follows:

$$\% \text{ output} = \frac{\text{output amount (ml) / \# drippers in that slab (bag)}}{\text{input amount (ml)}} \times 100$$

Example: 1000ml in, 1500ml out, 6 drippers: (1500ml/6)/1000ml X 100 = 25%

TYPES OF NUTRIENTS AND NUTRIENT SOLUTION RECIPES

*Mineral nutrients are available in several forms:

- **Pre-mixed liquid concentrates** that are then diluted with water.
  - “A” and “B” formulas (**see below): mix for all essential elements.
- **Pre-mixed powder concentrates** that are then diluted with water.
  - Many are a 1-teaspoon-per-gallon mix – fairly simple.
  - NOTE: DO NOT USE Miracle Gro – This is meant for soil culture and does not have all the essential elements for plant growth.
- **Made from “scratch”:** most commercial growers buy the individual compounds and mix the nutrient solution themselves.
  - See above under **Mineral elements or nutrients** for a list of typical compounds required (other compounds can be substituted).
  - **Macroelements (or macronutrients)** are usually purchased in 50 lb bags.
    - These are called **horticultural grade.**
    - These need to be in a **soluble form.**
    - Buy from a reputable company. The fertilizers should be of good quality with low or no impurities such as dirt/black specks, heavy metals, oils, “odd” colors, etc.
  - **Microelements** (needed in much smaller amounts) can be purchased as
    - Pre-mixed powders: specific for hydroponics.
    - Individual compounds: at least **horticultural grade**, but can be **technical or reagent grade** and need to be **soluble.**

**PRECAUTIONS:

Note above the "A" and "B" formulas… There is a reason…

Usually, the **calcium containing compounds**
  are kept separate from the **phosphate and sulfate compounds.**

Why? In <u>high concentration</u> (>50X) the calcium will combine with the phosphates and sulfates to form **insoluble precipitates.**

THEREFORE: A typical nutrient solution will be divided into **3 tanks:**

- **Calcium & potassium nitrates/iron tank** (Fe = reddish color)
- **Macro/Micro tank** (all other macro and micro elements)
- **Acid (or base) tank** (so pH can be adjusted individually)

Organic nutrients and recipes:

Organic recipes can also be made from sea weed, bat guano, fish flour, etc., or by creating "teas" by adding composted plant material to water. However, the nutrient composition may not be consistent and the organic solutions may contain particulate matter that can clog drip irrigation lines and emitters. Therefore, at the present time, most commercial hydroponic growers do not use organic fertilizers with drip irrigation systems. Some commercial growers ARE using compost beds and irrigating with plain water.

For more information about the use of organics in agriculture:
- USDA National Organic Program
- OMRI (Organic Materials Review Institute).

*How to find the perfect nutrient solution **recipe** (there are many variations).

Choose a recipe that has been successful:
- For the plant you want to grow.
- For your regional location and environmental conditions.
- For the time of year you wish to grow.

IF you notice deficiency/toxicity symptoms,
  THEN adjustments to the recipe can be made to compensate.

***An example:** CEAC tomato recipe (2018) for high light, high heat, arid climates.

Most recipes for fruiting crops will vary according to stage of plant growth.

pH should be ~6. EC is typically ~2.0 - 3.5 (but may vary ~1.2 - 4).

Ex:
- 0 – 6 Week recipe: lower nitrogen (because of climate conditions), for good structure/vegetative growth. Lower potassium, calcium.
- 6 – 12 Week recipe: Higher nitrogen and higher potassium to enhance flower (reproductive) production
- 12 + Week recipe: To maintain balance: vegetative = reproductive

CEAC Tomato Recipe (2018)

WEEK 0-6	**WEEK 6-12**	**WEEK 12 +**
PPM	**PPM**	**PPM**
N 90	**N 145**	**N 190**
P 47	**P 47**	**P 47**
K 144	**K 276**	**K 350**
Ca 160	**Ca 170**	**Ca 200**
Mg 65	**Mg 65**	**Mg 65**
Fe 2.0	**Fe 2.0**	**Fe 2.0**
S 121	**S 121**	**S 102**
Mn 0.55	**Mn 0.55**	**Mn 0.55**
Zn 0.33	**Zn 0.33**	**Zn 0.33**
Cu 0.05	**Cu 0.05**	**Cu 0.05**
B 0.40	**B 0.40**	**B 0.40**
Mo 0.05	**Mo 0.05**	**Mo 0.05**
pH 6.0 - 6.3	**pH 6.0 - 6.3**	**pH 6.0 - 6.3**
EC 1.2 – 1.8 mS/cm	**EC 2.1 mS/cm**	**EC 2.5 - 3.0 mS/cm**

NOTE: Sulfur (a macronutrient) and chloride (a micronutrient) concentrations are not given in this recipe. That does not mean that sulfur and chloride are not present. Usually sulfur is added with magnesium and potassium ($MgSO_4$ and K_2SO_4) and micronutrients. Chloride may be present in source water or may be added with the manganese and copper or added through addition of $CaCl_2$. Chloride levels should be 50-200ppm to improve fruit quality and taste. Enough will be added with these other elements to be sufficient (see calculations below).

NOTE: Two significant differences in the CEAC formula as compared to other formulae is adjustment in nitrogen level because of o**ur hot, high light area** to improve growth of the plants and quality of the fruit:
Nitrogen: Begin with low nitrogen (~90ppm, EC ~1.2) the first 6 weeks (avoids too much vegetative growth during the hot fall and encourages reproductive growth to start). Increase to 145ppm N (EC ~2.1) at week 6, then 190ppm (EC ~2.5-3) by week 12.

***A SAMPLE NUTRIENT SOLUTION CALCULATION** (how much of what…):

In this example use the **"injector system with bag culture"** design pictured at the end of this chapter.

Important factors: 1 ppm = 1 mg/l   1 gallon = 3.785 liters   2.2 pounds = 1 kg

Follow these steps to do the nutrient solution calculations (use numbers below):

1. What is the final concentration desired, in ppm, of a particular element?
2. Does the source water contain any essential elements (from water analysis)? If so, subtract that from what is needed (& save $$!).

3. You know the final concentration in ppm for a particular element,
   BUT you can't add an element – it is part of a compound.
   SO, what is the proportion of the element in the compound?
   From this, calculate (ratio) the ppm (mg/l) of the compound.
4. What is the size of the tank? (mg/l needed x tank size in liters).
5. If you use concentrated nutrient solution stock tanks and injectors:
   What dilution factor is the injector set for?
6. This gives the final amount (in grams, Kg, lb) of compound needed.
   NOTE: Do not round off until the end of your calculation!

In this example we use the Sunco Recipe, 12+ weeks (see above):
Always start with **<u>Calcium</u>** (it starts a "cascade" of calculations)

1. Total concentration of calcium desired = 170 ppm Ca
2. **In this example:** the source water contains = 29 ppm Ca

Therefore, amount of calcium needed = **141 ppm Ca**

BUT, we don't add the element Ca, we add the compound **<u>$Ca(NO_3)_2$</u>**:

3. The % of calcium in **$Ca(NO_3)_2$** (from bag) = 19 % (proportion of 0.19)
   Therefore, to find the ppm required for the <u>compound</u> calcium nitrate set up a ratio:

$$\frac{141 \text{ ppm Ca}}{0.19 \text{ (prop of Ca)}} = \frac{X \text{ ppm CaN}}{1.0 \text{ (prop of CaN)}} \qquad X = 742.105 \text{ ppm} \quad \underline{\text{or } 742.105 \text{ mg/l}}$$

4. **In this example** the nutrient tank size is = 50 gallons
   BUT ppm is mg/LITER not gallons, so

$$50 \text{ gallons} \times 3.785 \frac{\text{liters}}{\text{gallon}} = 189.25 \text{ liters}$$

Therefore, the amount of calcium nitrate required for a 50 gal. tank is
742.105 mg/l x 189.25 liters = <u>140,443.37 mg</u>

5. HOWEVER, **in this example** the solution will also go through an injector system with the dilution rate set at 1:200.

140,443.37 mg x 200 = 28,088,674 mg

6. This is the FINAL amount of calcium nitrate required to obtain a final calcium concentration of 141 ppm of Ca:

<u>IF your scale is in kilograms</u> (kg=10^6 mg)
Then 28,088,674 mg / 1,000,000 mg/kg = **28.088674 kg calcium nitrate for 141 ppm Ca**

IF your scale is in pounds (lb)
Then 28.088674 kg x 2.2 lb/kg = 61.795 lb calcium nitrate

OKAY… So you've added the appropriate amount of calcium nitrate to get 141 ppm of Ca…

BUT**, how much Nitrogen did you add?** NEED TO WORK BACKWARDS!

6. The final amount of calcium nitrate = 28,088,674 mg

5. Divide by the dilution factor (200) = 140,443.37 mg

4. Divide by 189.25 liters in a 50 gal tank = 742.105 mg/L (ppm)

3. The amount of nitrogen in calcium nitrate (from bag) = 15.5%
The ratio:

$$\frac{\text{0.155 (prop N)}}{\text{1.0 (prop. CaN)}} = \frac{\text{X ppm N}}{\text{742.105 ppm CaN}}$$

X = 115 mg/l or **115 ppm N from calcium nitrate**

2. No N in the source water

HOWEVER, the total N that is needed from the recipe (week 12+) = 189 ppm
The difference is 189ppm – 115ppm (from $Ca(NO_3)_2$) = 74 ppm

1. This **74 ppm of Nitrogen** will come from potassium nitrate – **KNO_3**
2. Again, no N in water
3. Instead of getting the % of nitrogen from the bag…

Calculate the % of nitrogen in potassium nitrate using molecular weights
(see a Chemistry book/periodic table for a list of atomic weights)

MWt KNO_3 = K(39.1) + N(14) + 3O(3X16=48) = 101.1

AWt N (14) / MWt KNO_3 (101.1) = 0.1385 or 13.85% N

To find the ppm required for the compound potassium nitrate
Set up the ratio

$$\frac{\text{74 ppm N}}{\text{0.1385 (prop N)}} = \frac{\text{X (ppm KNO3)}}{\text{1.00 (prop KNO3)}} = \text{534.3 ppm or 534.3 mg/l}$$

4. Take into account the tank size (50 gallons or 189.25 liters)

534.3 mg/l x 189.25 liters = 101,116.275 mg

5. Take into account the dilution factor (1:200)

101,116.275 mg x 200 = 20,223,255 mg

6. OR 20,223,255 mg / 10^6 mg/kg = **20.223255 kg of KNO_3 for 74 ppm N**

BUT, **how much potassium did you add when you added 20.2 kg of KNO_3**?
YOU HAVE TO WORK BACKWARDS, AGAIN!

Convert back to mg:

6. 20.223255 kg x 10^6 mg/kg = 20,223,255 mg

5. Dilution factor: 20,223,255 / 200 = 101,116.275 mg

4. Tank size: 101,116.275 mg /189.25 liters = 534.3 mg/l or ppm

3. % K in KNO3: AWt K (39.1) / MWt KNO_3 (101.1)
= 0.3867 or 38.67% K

The ratio:

$$\frac{0.3867 \text{ (prop K)}}{1.00 \text{ (prop KNO3)}} = \frac{X \text{ ppm K}}{534.3 \text{ ppm KNO3}}$$

= **206.6 ppm K added with 20.2 Kg KNO_3**

HOWEVER, the total **K** needed from the recipe is **341 ppm**.

2. And there is no K in the water.

The difference is 341 (needed) – 206.6 (fr. KNO3) = **134.4 ppm K** still needed

To get the rest of the needed **K use KH_2PO_4**.

HOWEVER, this is the **only source for Phosphorus**. STOP!

THEREFORE, figure the P, or phosphorus, first.

1. Need **39 ppm P (phosphorus) from KH_2PO_4**

2. There is no P in the source water.

3. Figure the % P in KH_2PO_4 using molecular weights:

MWt KH_2PO_4 = K (39.1) + 2H (2x1+2) + P (31) + 4O (4x16+64) = 136.1
AWt P (31) / MWt KH_2PO_4 (136.1) = 0.2278 or 22.78% P

The ratio:

$$\frac{\text{39 ppm (mg/l) P}}{\text{0.2278 (prop of P)}} = \frac{\text{X mg/l } KH_2PO_4}{\text{1.0 (prop } KH_2PO_4\text{)}} \qquad \text{X = 171.2 mg/l } KH_2PO_4$$

4. Tank size: 171.2 mg/l x 189.25 liters = 32,399.6 mg KH_2PO_4

5. Dilution factor: 32,399.6 x 200 = 6,479,920 mg KH_2PO_4

6. Final amount of KH2PO4 needed:
Conversion: 6,479,920 mg / 10^6 mg/Kg = **6.47992 Kg KH_2PO_4**

To figure the amount of <u>K</u> added from 6.47992 Kg <u>KH_2PO_4</u>,
WORK BACKWARDS

5. Dilution factor: 6,479,920 mg KH_2PO_4 / 200 = 32,399.6 mg KH_2PO_4

4. Tank size: 32,399.6 mg KH_2PO_4 / 189.25 l = 171.2 mg/l KH_2PO_4

3. % K in KH_2PO_4 = AWt K (39.1) / MWt KH_2PO_4 (136) = 0.2875
or 28.75 % K

The ratio:

$$\frac{\text{0.2875 (prop K)}}{\text{1.0 (prop KH2PO4)}} = \frac{\text{X (mg/l K)}}{\text{171.2 mg/l } KH_2PO_4} \qquad \text{X = } \textbf{49.2 mg/l or ppm K from } \mathbf{KH_2PO_4}$$

Total K so far = K from KNO_3 (206.6ppm) + K from KH_2PO_4 (49.2ppm)
= **255.8 ppm K**

2. Still with no K in the source water.

HOWEVER, total K needed from recipe = 341 ppm

341 ppm K – 255.8 ppm K = **85.2 ppm K still needed. Use <u>K_2SO_4</u>**.

1. Need 85.2 ppm of K from K2SO4.
2. Still no K in the source water.
3. Figure % K in K_2SO_4 by using molecular weights.
MWt K_2SO_4 = 2K (2x39.1=78.2) + S (32.1) + 4O (4x16=64) = 174.3
AWt K (78.2) / MWt K_2SO_4 (174.3) = <u>0.4487 or 44.87% K</u>
The ratio:

$$\frac{\text{85.2 ppm K}}{\text{0.4487 (prop K)}} = \frac{\text{X ppm K2SO4}}{\text{1.0 (prop K2SO4)}} \qquad = \text{189.9 ppm or mg/l } K_2SO_4$$

4. Tank size:189.9 mg/l K_2SO_4 x 189.25 l = 35,938.575 mg K_2SO_4

5. Dilution factor: 35,938.575 mg x 200 = 7,187,715 mg K_2SO_4

6. = **7.187715 Kg K_2SO_4 to get 85.2 ppm K**

Final total of K = K from KNO_3 (206.6 ppm) + K from KH_2PO_4 (49.2 ppm)
+ K from K_2SO_4 (85.2 ppm) **= 341 ppm K**

NOTE: **S is also added in K_2SO_4**. How much S? WORK BACKWARDS

5. Dilution factor: 7,187,715 mg K_2SO_4 / 200 = 35,938.575 mg K_2SO_4

4. Tank size: 35,938.575 mg K_2SO_4 /189.25 l = 189.9 mg/l K_2SO_4

3. % S in K_2SO_4 = AWt S (32.1) / MWt K_2SO_4 (174.3) = 0.184 or 18.4%
The ratio:

$$\frac{0.184 \text{ (prop of S)}}{1.0 \text{ (prop of } K_2SO_4)} = \frac{X \text{ ppm S}}{189.9 \text{ ppm } K_2SO_4} \qquad X = \textbf{34.9 ppm of S from } \mathbf{K_2SO_4}$$

2. No S in the source water.

Finally 1. calculate the **amount of $MgSO_4 * 7H_2O$ needed to give 48 ppm Mg.**
2. No Mg in the source water.
3. From the bag, the % Mg in $MgSO_4 * 7H_2O$ = 9.8%
The ratio:

$$\frac{48 \text{ ppm Mg}}{0.098 \text{ (prop of Mg)}} = \frac{X \text{ ppm } MgSO_4{*}7H_2O}{1.0 \text{ (prop of } MgSO_4{*}7H_2O)}$$

X = 489.8 ppm or mg/l $MgSO_4 * 7H_2O$

4. Tank size: 489.8 mg/l $MgSO_4 * 7H_2O$ x 189.25 liters
= 92,694.65 mg $MgSO_4 * 7H_2O$

5. Dilution factor: 92,694.65 mg $MgSO_4 * 7H_2O$ x 200
= 18,538,930 mg $MgSO_4 * 7H_2O$
6. Conversion: 18,538,930 mg $MgSO_4 * 7H_2O$ / 10^6
= 18.538930 Kg $MgSO_4 * 7H_2O$ needed to get 48 ppm Mg

But, **how much S is added?** WORK BACKWARDS (ppm of S not specified)
6. Added 18,538,930 mg $MgSO_4 * 7H_2O$

5. Dilution factor: 18,538,930 mg $MgSO_4 * 7H_2O$ / 200
= 92,694.65 mg $MgSO_4 * 7H_2O$

4. Tank size: 92,694.65 mg $MgSO_4 * 7H_2O$ / 189.25 l
= 489.8 mg/l or ppm $MgSO_4 * 7H_2O$

3. From the bag the % S in $MgSO_4 * 7H_2O$ = 12.9%
The ratio:

$$\frac{0.129 \text{ (prop of S)}}{1.0 \text{ (prop of MgSO4)}} = \frac{X \text{ ppm S}}{489.8 \text{ ppm } MgSO_4 * 7H_2O}$$

X = **63.2 ppm S from 18.538930 Kg $MgSO_4 * 7H_2O$**

2. No S in the source water.

1. The final amount of S added
= 63.2 ppm (from $MgSO_4 * 7H_2O$) + 34.9 ppm (from K_2SO_4)
= **98.1 ppm S**

FINAL NOTES: Calculations for the microelements are done the same. Always take into account the desired concentration (ppm), the amount of element in the source water, the percentage of the element in the compound, the tank size and the dilution factor if injectors are used. However, micronutrient amounts will be in the gram or mg range.

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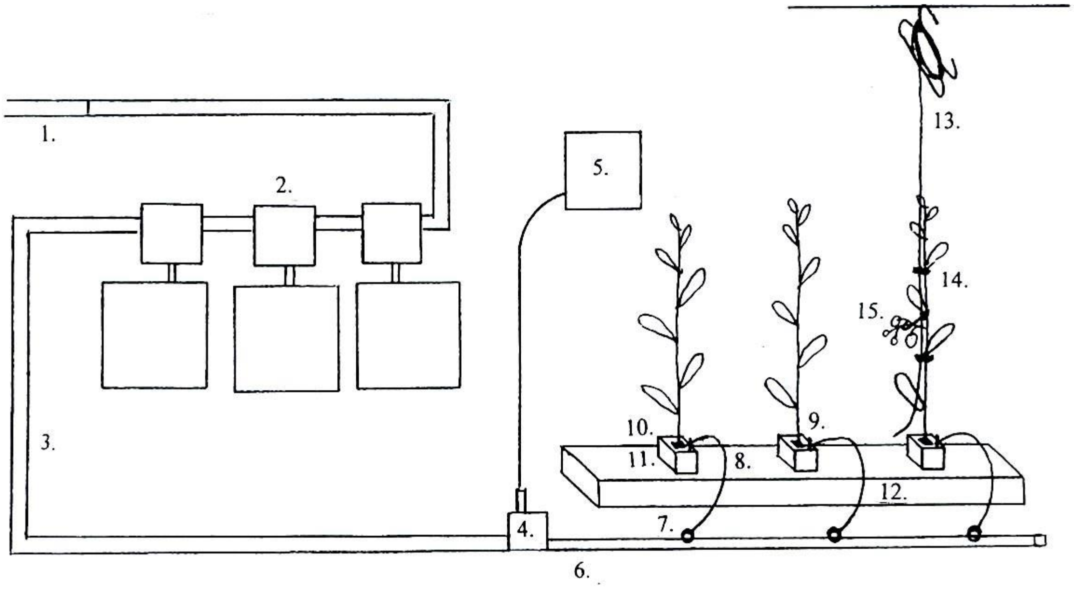

Injector system with bag culture (example: vining crop with fruit clusters)

1. PVC: Source water input (should include an inline pressure gauge)
2. Injectors (various designs – usually require either air or water pressure to operate)
    Injectors pull concentrated nutrient solution from tanks through tubes
    Concentrated solution is diluted by the injectors and added to supply line
    Some designs include a mixing tank before solution is sent to the plants
3. PVC connection pipe (from injectors to solenoid valve)
4. Solenoid valve (opens and closes according to programming from controller)
    Can be positioned before or after (as shown) the injectors
5. Irrigation controller (various designs – programmed to properly fertigate the crop)
6. Poly pipe (runs along each row of plants – closed at the end with cap or crimper)
7. Dripper/Emitter (controls the amount of solution applied: i.e., 0.5 gallons/hour)
8. Feed tube (carries solution from poly pipe/dripper up to the plant)
9. Stabilizer peg (various designs – holds feed tube in place at the base of the plant)
10. Propagation cube (various sizes – used for starting seedlings)
11. Propagation block (various sizes – seedlings transplanted into blocks)
12. Slab/bag (various sizes and fillers – filled with the grow-out medium)
13. Vine twine wound onto tomahook/other support device (to support the plant)
14. Vine clip (clamps onto twine and clips around stem under sturdy leaf for support)
15. Truss hook (various designs – used to support fruit truss/cluster)