Return to the Source



The 2012 / 2013 *Grower's Guide* volume one.

The original text of this edition was first published in the UK by *HYDRoToPS* © 2001 (wishing well publications) second edition *HYDRoToPS* © 2004

This revised edition published by *HYDRoToPS* the next generation ltd. © 2012.

All rights reserved.

No part of this publication may be reproduced or transmitted in any form or by any means without the direct written consent of the Publisher.

Design and artwork by Matt Tweed © 2012.

Text set in Helvetica

Printed by Fossway Press

Radstock , Somerset.

Grower's Guide

top tips for happy plants - Vol. 1



HYDROTOPS™

Contents

1.	Foreword	1
2.	Water Quality	8
2.1.	Understanding Your Tap Water Quality	8
3.	Water Quality and Nutrient Choice	10
3.1.	Working with Hard Water	11
3.1.1.	Hard Water Nutrients	13
3.2.	Working with Soft Water	15
3.2.1.	Soft Water Nutrients	17
4.	Managing Nutrient Solutions	17
4.1.	General Temperature Considerations	18
4.2.	General EC and pH Considerations	20
4.3.	Nutrient Management in Re-circulating Systems	24
4.3.1.	NFT / Bubbler Systems	24
4.3.2.	Watering Frequencies and EC	29
4.3.3.	Conditioning the Growing Media	30
5.	*HYDRoToPS biOpOnic* Nutrients	31
5.1.	Approaches	32
5.2.	Simple Approach Nutrient Program	34
5.2.1.	*biOpOnic Bactivator*	35
5.2.2.	*Head Start*	37
5.2.3.	Propagation Tips using *biOpOnic Head Start* and *biOpOnic Root Stimulator*	39
5.2.4.	*biOpOnic Grow*	41
5.2.5.	*biOpOnic Bloom*	42
5.2.6.	*biOpOnic Floral Boost*	42
5.3.	Enhanced Approach Nutrient Program	44
5.3.1.	*biOpOnic Root Stimulator*	45
5.3.2.	*Triple F – Fully Formed Flowers*	46
5.3.3.	*biOpOnic Flush*	48

5.4.	Complete Approach Nutrient Program	50
5.4.1.	*biOpOnic Leaf Feed*	51
5.4.2.	*biOpOnic Flower Feed*	52
5.4.3.	*Top Heavy Crop*	53
6	Your Growing Environment	55
7	The Root Environment	56
7.1.	Oxygen Levels and Drainage	57
7.2.	The Nutrient Solution	59
8	The Photoperiodic Environment	60
8.1.	Getting the Best from your Light Source	62
8.1.1.	600 Watt Lights	67
8.1.2.	400 Watt Lights	68
8.1.3.	250 Watt Lights	68
9.	The Shoot Environment	70
9.1.	Ventilation (Air Exchange)	71
9.2.	Stratification Control (Air Movement)	74
9.3.	Air Temperature	76
9.4.	Relative Humidity	78
9.5.	Carbon Dioxide (CO_2)	79
9.5.1.	The Light / Carbon Dioxide Link	80
9.5.2.	The Temperature / Carbon Dioxide Link	81
9.5.3.	The Relative Humidity / Carbon Dioxide Link	81
10.	Glossary of Terms	82
11.	*HYDRoTopS biOpOnic* Feeding Schedule	85
12.	Grower's Notes	88



1. Foreword

When designing our *biOpOnic* nutrient range back in 1998 the principal aim was to combine organic horticultural chemistry with the spirit and ethos of the organic grower, drawing upon in-depth knowledge of hydroponic growing and nutrients.

HYDRoToPs was the first UK based nutrient manufacturer, and whilst our products have evolved over the last 16 years our aims have remained the same; to produce high performance bio-organic nutrients that deliver consistent outstanding results for both hydroponic, coco and soil growers.

HYDRoToPs is proud to have introduced many ground breaking ideas and concepts to the hydroponic world. One such example is our legendary *Triple F* (Fully Formed Flowers). Introduced to the world in 2002 it was the first fruit and flower enhancer to increase yields by up to 40% whilst remaining 100% organic.

Triple F continues to prove itself time after time as the finest natural flowering enhancer available to date. Its introduction to the market over 10 years ago prompted a number of flower boosting products to emerge from other manufacturers. Sadly many of these products have evolved from using plant growth regulator (PGR) chemicals to achieve their results. Whilst many of these products are successful at producing additional flowers and increasing yields, we believe nature offers the best solution every time.

Many of the PGRs used in boosters today MUST be licensed and are for use on non food crops ONLY. There is a reason for these regulations to be in place since many of these chemicals are known to have carcinogenic effects and may be linked to the development of serious medical conditions. *HYDRoToPS* never has and never will

use PGRs or other dubious chemical additives which may cause harm. Alarmingly enough some PGRs are yet to be classified or approved and little or no research has been done on the potential risks to health or the environment.

PGRs have found their way into several manufacturers' "boost" products hailed as a breakthrough in growing technology. Most have been banned in the USA owing to their associated health risks. Whilst some growers may not be driven by conscious choice in terms of which products they use, many are consciously opposed to using products which may cause harm to the individual or environment. *HYDRoToPS* gives you a better result naturally without recourse to potentially dangerous compounds and chemicals.

We are always actively researching and developing our products and we are excited to announce some new additions to our range, which will be released in the coming months. For example our Next Generation range of nutrients, plus *Top Heavy Crop* - a formidable new growth and flowering enhancer.

The word hydroponics derives from the Greek to mean "water working". *HYDRoToPS* was the first company in the world to introduce the concept of nutrients tailored directly to your regional or personal water supply. In order for your water to work for you the nutrients you use need to be chosen carefully and balanced to your water supply. Within this guide you will find an in depth explanation of water quality and plant nutrients, allowing you to make the best decision when choosing your own nutrient requirements thus allowing you to achieve maximum results from your efforts.

HYDRoToPS have been producing custom nutrient formulations for UK growers since 1996 and continue to do so to this day. We also were the first to manufacture area specific nutrients covering all of the UK by 2005.

Over the last 13 years we have analysed thousands of water samples from all areas of the UK and our data base of water quality second to none. We are very proactive in the maintenance and expansion of our water quality data base, constantly re-analysing water samples from growers and *HYDRoToPS* distributors, free of charge. This helps us to maintain the excellent quality of service growers throughout the country have come to expect. This ensures our products are the most effective and productive nutrients available in the UK today.

Happy Growing,

HYDRoToPS

2. Water Quality

Water is described as being either hard or soft in quality. In the UK approximately 70% of the country's water supplies are considered moderately hard to very hard. The remaining 30% of water supplies are classed as soft. To achieve the best results it is critical to understand the water quality of the area in which you grow. This allows for selection of the most appropriate nutrient concentrates thereby ensuring your growing success.

2.1. Understanding Your Tap Water Quality

When asking "What makes water hard or soft?" the answer is literally beneath your feet. Fallen rainwater soaks into the ground to form underground water deposits known as the Water Table. It can also flow directly into the river system and reservoirs as surface water. The geological conditions of your area dictate the type and quantity of minerals that dissolve into the water rendering it either hard or soft.

For example; if the rock beneath the soil in your area is limestone, the slightly acidic rainwater will soak through the limestone before contributing to the Water Table. During its journey to the Water Table. The water will dissolve small quantities of minerals from the limestone it passes through. The longer it takes for the rainwater to pass through the rock, the higher the quantity of minerals that dissolve into it, contributing to its "hardness" and elevating its pH. Hard water is further discussed in Section 3.1.

In an alternative case, if the rock beneath the soil in your area is granite, or you live near a peat deposit, the rainwater will not contain high concentrations of minerals attributed from the rock or peat it has drained through.

This water is classified as soft and the pH can vary from as low as 5.5 to 7.0 (neutral) because of other factors such as acidic rain.

It is possible to determine how hard or soft your water supply is by analysing the quantity of dissolved minerals using an Electrical Conductivity (EC) meter. The EC meter works by measuring how easily your water conducts electricity. When high quantities of minerals are dissolved in the water, it conducts electricity easily and a high EC reading (0.4 - 1.2 EC) is recorded. With soft water a low reading is recorded (0.1 - 0.3 EC).

A simple way to check if your water is hard or soft is to look at the inside of your kettle. If the element or base is furred up with a white deposit you can safely assume that the water quality in your area is hard. However to know the severity of your areas hardness you will need to test it with an EC meter. These meters are fairly inexpensive and represent a great investment. Without one you will find it impossible to get the best results.

To attain accurate readings you will require a good quality EC meter that is calibrated regularly. All EC meters are also temperature sensitive and the EC of a measured solution will fluctuate in relation to solution temperature. The best meters include a temperature probe and automatically adjust the reading to the temperature of the solution being tested.

The table contained in the following section on Water Quality Nutrient Choice gives a general description of water quality by EC reading and some recommendations on the best type of nutrient for your use.

3. Water Quality and Nutrient Choice

The majority of hydroponic nutrients sold in the UK are produced and imported from Europe. They are typically designed for water conditions found in mainland Europe, which are mainly hard water. In areas of the UK with soft water, if the manufacturer produces a nutrient designed for soft water this is often not so problematic. Conversely in areas of hard water quality there are complications. Even nutrients produced by UK manufacturers are typically generic hard or soft water nutrient blends.

Problems with generic nutrients arise because they only allow for a certain level of minerals already present in the water and these vary from area to area. Generic nutrient blends rarely produce a balanced working nutrient solution. Unbalanced nutrient solutions often lead to nutrient deficiencies, all of which ultimately leads to less than optimal results.

HYDRoToPS was the first nutrient company to address this issue back in 1996 by producing nutrients tailored to the water quality of specific areas. Additionally, *HYDRoToPS* continues to offer small volumes of custom made nutrients individually tailored to a customer's water supply. This approach to nutrients is the reason for the wealth of success that growers experience when using *HYDRoToPS*.

At *HYDRoToPS* we have the facilities to analyse your tap water and advise you of the best choice of nutrient concentrate for your requirements. In some cases where custom formulated nutrients are required, amounts as small as 10 litres can be produced for a customer. For further information regarding *HYDRoToPS* custom nutrient and nutrient advice service please contact your local *HYDRoToPS* retailer to request a water sample analysis pack.

Water Quality	Background EC	Hardness	Nutrient Choice
Very soft water	E.C. level 0.0 to 0.1	< 30 parts per million hardness	Buffered soft water
Soft water	E.C. level 0.1 to 0.3	30 - 100 parts per million hardness	Buffered soft water
Borderline water	E.C. level 0.4 to 0.5	100 - 150 parts per million hardness	Custom nutrient or *HYDRoToPS* area specific nutrient
Hard water	E.C. level 0.5 to 0.8	150 - 280 parts per million hardness	Custom nutrient or *HYDRoToPS* area specific nutrient
Very hard water	E.C. level 0.8 to 1.1	> 280 parts per million hardness	Custom nutrient or Reverse Osmosis formulation

3.1. Working with Hard Water

From the above table when the background EC of the water sample is between 0.5 and 1.1 it is classified as hard water. In these samples the dissolved compounds are predominantly from bicarbonates, calcium, magnesium, and other elemental compounds. A higher EC will denote a higher quantity of these compounds present in the water sample, but will not reveal the exact ratios which also vary between locations.

Whilst calcium and magnesium are vital elements

for plant growth it is the bicarbonate (HCO_3^-) content that gives the water a high pH (typically between 7.4 to 8.5). To avoid buffering problems in the nutrient solution the bicarbonates present in hard water need to be neutralised. Acidic compounds are routinely included in the manufacturing process of generic hard water nutrients to neutralise bicarbonates, however it is essential to leave a sufficient amount of bicarbonates present in solution to buffer the nutrient against wide changes in nutrient pH. The inclusion of acidic components during manufacturing naturally lowers the pH of the nutrient solution to a suitable level for your plants to assimilate the nutrients they require. For optimum nutrient assimilation the pH of the nutrient solution should remain between 5.8 and 6.5. With *HYDRoToPS* products we recommend that you maintain your nutrient solution pH in the middle of this range.

When mixed to full strength, generic hard water nutrient concentrates routinely need to be further adjusted with pH Down or in some cases pH Up. pH Down works by adding phosphoric acid or nitric acid to the nutrient solution. These acids will reduce the pH effectively but if used excessively will affect the nutrient balance. In hard water areas the addition of phosphoric acid can cause precipitation of insoluble calcium from the nutrient solution and simultaneously oversupply phosphorous. Both will result in nutrient balance problems and poor growing performance. Excessive phosphorus can also lead to iron deficiency, so nitric acid (pH Down Grow) is a more preferable alternative.

Compounding nutrient balance issues, the addition of large quantities of pH Down results in the EC of the nutrient solution rising. This makes it difficult to supply a balanced nutrient solution at the correct EC to reflect the plants stage of growth. This is critical during the vegetative period since during this period nutrient uptake directly affects the final crop at harvest.

3.1.1. Hard Water Nutrients

As previously highlighted it is impossible to produce a generic nutrient which performs well across the full spectrum of hard water quality found in the UK. To tackle this issue *HYDRoToPS* started producing Area Specific Nutrients as early as 1996. Today we no longer produce a standard hard water formulation in our *biOpOnic* range as it has been superseded by our superior Area Specific Nutrient Formulations.

When designing an area specific nutrient, *HYDRoToPS* collect and analyse hundreds of water samples within a specified radius of your supplier. This process allows us to formulate a nutrient concentrate with a nutrient profile as close to optimum as possible. We also design our nutrients to ensure the pH always remains stable within the most favourable growing range.

To achieve a consistent pH we buffer the nutrient concentrate to ensure the pH of the working nutrient solution requires very little to no adjustment between nutrient changes when used as directed. This refined approach to nutrient formulation allows the grower to achieve a consistent nutrient profile, stable pH and EC resulting in the best possible plant development.

Whilst our Area Specific Formulations achieve excellent results, within the UK there are isolated pockets of exceptionally hard water or in some instances extremely soft water which often require the employment of our Custom Nutrients. In these isolated cases the levels of calcium, magnesium and trace elements are often very high or are present at very low levels. Even in areas of moderately hard water our research has found that magnesium and trace element levels can be abnormally high.

If generic hard water concentrates are used where such cases arise it is highly likely that calcium and magnesium

will be oversupplied to your plant. The oversupply of these elements in a nutrient solution can interfere with the plant's ability to assimilate other vital elements like potassium, and in areas where the level of magnesium is unusually high, calcium and potassium uptake can be compromised. When this fine nutrient balance is upset it can have a dramatic effect upon plant performance. This is often observed in the form of poor flowering and low fruit production. This is particularly problematic in re-circulating systems like NFT and bubbler systems if the EC is rising.

Another caveat arises, *i.e.* the situation outlined above relates to the common practice of adding tap water to reduce the EC of the nutrient solution. By adding additional tap water the levels of calcium and magnesium and other elements are further increased/oversupplied from the inclusions present in the hard tap water. This action will ultimately push the nutrient solution profile further away from the optimum level, further hampering plant performance.

If the EC of your tap water is 0.8 or higher, an alternative to custom formulated nutrient concentrates is to use *Reverse Osmosis (RO)* water. An RO filter removes nearly all minerals present in your tap water and will reduce the EC from 0.8 and above to 0.1 or less, depending on the quality of your filter system. Some water supplies are so poor that only RO water can be used, though these conditions are very rare in the UK

One final word on water filtering, if you have a water softening filter fitted to your water supply it is essential that you collect your water for growing from a tap that is not connected to the filter. Water softeners add sodium salts to your water as part of the softening process. Excessive sodium will poison your plants.

If you are in an area of very hard water or are experiencing problems PLEASE ask you supplier for a water sample pack. *HYDRoToPS* Custom Nutrients may be the best way forward.

3.2. Working with Soft Water

In areas of soft water the background EC of the water supply often ranges from 0.0 to 0.4. Similarly the pH of the water can be as low as 6.0 and as high as 7.2. In soft water the levels of calcium, magnesium, and bicarbonates are relatively low. Generic soft water nutrients are thus manufactured to supply higher levels of these vital elements, and acidic compounds are not generally used in the manufacturing process.

Although additional acid is not required to neutralise excessive amounts of bicarbonates in soft water, soft water nutrients can naturally be acidic in nature. This can cause the pH of the nutrient solution to fall below the desired range for optimum nutrient uptake and plant growth (5.8 to 6.5). The nutrient solution is also left with little to no buffering capacity to ensure a stable pH of the nutrient solution, so swings in pH are often observed. Frequently pH Up solution is added when the pH of the nutrient solution is too low. pH Up solutions are normally made from potassium hydroxide. The addition of extra potassium from the potassium hydroxide to the nutrient solution can lead to potential problems with calcium and magnesium assimilation. To promote plant growth it is vital these two elements are supplied when needed.

Superior soft water nutrients contain a buffering system to ensure the full strength nutrient solution remains at a stable pH. In areas of exceptionally soft water signs of magnesium deficiency are often reported as a direct influence of excessive amounts of added pH Up. In these

cases the excessive addition of potassium results in total magnesium lock out. Again Re-circulating systems, where water is used to top up the nutrient tank as the EC rises, suffer more readily. This occurs because as more water is added the pH falls requiring further addition of pH Up, which in turn increases the concentration of potassium to the solution.

In soft water areas such as Birmingham, Bradford, Leeds, Strathclyde, Lothian, Fife, Greater Manchester and South Wales the local water supplier treats the water by adding alkaline reagents to increase the natural pH of the water. This is done to prevent the acidic water causing damage to pipe work through corrosion and is becoming increasingly common practice. In these areas it is necessary to adjust the buffering in the nutrients to avoid problems with pH stability and the chemicals used to treat the water taken into consideration when formulating a nutrient concentrate. Additionally in some the above areas such as Bradford, Lancaster and Strathclyde the levels of mineral inclusions in the tap water are so low that standard soft water nutrients will not perform too well. This will often be seen as poorly developed flowers or fruit.

In some areas the water quality will be borderline between hard and soft. When using a standard soft water nutrient with borderline water supplies both calcium and magnesium are often oversupplied, which can bring about a potassium deficiency. In addition fairly large amounts of acid may be required to lower the pH of the solution altering the nutrient profile away from optimum. Areas of soft water containing above average levels of magnesium have also been discovered during our research. In these circumstances using a *HYDRoToPS* Custom or Area Specific Nutrient will circumnavigate potential problems and make managing the nutrient solution less demanding.

3.2.1. Soft Water Nutrients

HYDRoToPS Universal Soft Water Nutrients are designed to give exceptional results within all soft water areas where the EC is between 0.0 to 0.3. Our high quality soft water nutrients are buffered to maintain a stable pH over the best possible range reducing the growers work load with respect to nutrient management. In Soft Water areas with very low tap water inclusions such as Scotland, South Wales, Bradford and Leeds we produce area specific soft water formulations to ensure the optimal nutritional balance.

If the EC of your water is 0.4, or you are experiencing problems, *HYDRoToPS* Custom Nutrients should be considered if your supplier is not offering area specific formulations. In either case you can arrange to collect a water analysis sample pack from your local supplier. Upon analysis of your water sample at our facilities which we provide free of charge, we are able to advise as to why you are experiencing difficulties. The production of a custom formulation tailored to your water supply may be necessary to circumnavigate certain problems.

4. Managing Nutrient Solutions

Correct nutrient management is at the heart of achieving the best results from your crop and is necessary irrespective of growing method. Hydroponic growing systems mainly fall into two categories, Re-circulating or Run to Waste. Examples of Re-circulating systems include NFT, bubbler systems and Ebb & Flow. Examples of Run to Waste systems include Rockwool/coco slabs under drip irrigation, or coco in pots watered by hand. Since Run to Waste systems have become less popular in recent years, the guide below is aimed at re-circulating systems.

It is critical during nutrient solution management that the EC/strength of the nutrient solution is set at the right level for the plant's stage of growth. When small plants are first placed into the growing system, root growth is not especially developed and their nutritional needs are low. As the plant begins to grow the strength of the nutrient solution can be increased. This is best done gradually and the plant can visually guide you as to the best nutrient strength to use.

As the plant removes water and various nutrients from the tank the EC will fluctuate. In correctly set solutions the reading should stay within 0.1 or 0.2 EC points of where it was originally set. An effective method to monitor the correct strength of your nutrients is to employ a simple formula: when the plant has taken 25% of the solution from the tank, then measure the EC. If the EC has risen 0.3 EC points or more, the strength of the nutrient is too high. If the EC remains the same as originally set or is falling, you can increase the strength of the solution slightly. This formula is known as the "Feeding on Demand" or the "Plant Driven Feeding Rule". Daily measurement of the EC and making the corresponding adjustment takes more time and effort, but will result in a better performing plant.

4.1. General Temperature Considerations

It is always advisable to set the EC to a lower strength than normal when the environment (air and nutrient solution) temperature is high. High temperatures coupled with a high EC results in the EC of the tank rising rapidly when the nutrient solution is too strong. This is caused by the plant's need for water increasing in response to increased temperatures. The principle is the same with humans. When it's hot you drink more fluids and eat less hearty food: remember that the same applies to your plants.

High environment temperatures can also create high nutrient solution temperatures. When the nutrient solution temperature is raised the oxygen content of the solution will be diminished, which could lead to root system damage. It is important to remember a damaged root system is more vulnerable to infections such as *pythium* which cause root rot. Plants with root rot display symptoms of brown spongy roots and the pH of your nutrient solution will start to fall noticeably. We suggest that you always oxygenate the nutrient solution and keep the nutrient temperature below 18 °C.

Air temperatures above 30 °C are detrimental to plant growth and make it difficult if not impossible to manage your nutrient solution correctly. High air temperatures = Increasing EC levels = poor growth

Knowing that the EC reading is temperature dependent, if your nutrient solution runs at a temperature of 18 °C your meter should be calibrated with EC standard solution at this temperature for the most accurate readings. Most meters are standardised at a given temperature and this information should be on the label of the calibration solution you are using. Make sure your calibration solution is close to the ideal temperature before you use it to calibrate your meter.

When you are testing the EC of a nutrient solution freshly made, if the temperature is below your normal running temperature you will obtain a false reading. For example you may set your EC to 1.9 when the nutrient solution temperature is 16 °C. As the solution temperature rises so will the EC reading. The EC you set at 1.9 may turn out to be 2.1 or 2.2 when the solution comes up to normal operating temperature.

4.2. General EC and pH Considerations

When the EC rises, it is common place to add water to lower the nutrient solution strength. This is not a recommended approach, especially if the EC has risen sharply. By adding further quantities of your water supply, extra calcium, magnesium, and other minerals in the water are added to the nutrient solution. Without balancing these additions with other required macro and micro elements like nitrogen, phosphorous, and potassium, excess magnesium and calcium will accumulate in the nutrient solution resulting in a solution that is unbalanced. This will eventually lead to certain nutrient deficiencies/lock out and ultimately restricted plant growth. In areas of soft water where the EC of your tap water is 0.1 or less, adding water to the nutrient solution is acceptable for one to two instances. Soft water is more flexible than hard water since soft water contains lower concentrations of dissolved minerals and so excessive build up is less likely to occur. The pH of soft water is characteristically more neutral (pH 7) so requires less pH Down to reset the pH to the correct level upon addition of your plain water supply.

In areas of hard water where high quantities of dissolved minerals are present in the water, and at times considerable levels of sodium, problems resulting from nutrient imbalance become pronounced at an accelerated rate. When adding “topping-up-water” it is also necessary to add acid to restore the pH to an acceptable level. The inclusion of acids like phosphoric acid has consequential effects upon the availability of calcium and iron. The addition of the acid itself will also increase the EC adding additional nitrogen or phosphates depending on which type of acid is used. This will result in a nutrient solution further out of balance with a greater potential for nutrient deficiencies to develop.

In an ideal situation with a balanced nutrient solution set at the correct EC for the stage of growth, it will be necessary to top up the tank with pre-made nutrient solution, not plain tap water. Please note that when using re-circulating hydroponic growing systems, it is necessary to top up the nutrient solution volume from time to time to replace the solution removed by the plants. The nutrient solution used to top up the system may be weaker (lower EC) than the usual strength used. Air temperatures and nutrient take up will dictate how strong the top up solution should be. Each case is individual and you will need to experiment to decide the best approach for yourself..

It is not possible to get the EC levels perfect all of the time as you contend with the changing nutrient demands of the plant in conjunction with the environmental factors such as high temperature; however working with the previously outlined principles will go a long way to improving yield and crop quality.

There are no hard and fast rules as to how high you can set your EC. If the plant continues to take up nutrients and water equally, and the EC remains stable as the solution level falls in the reservoir, you can incrementally increase the EC to match your plant's demand. It is typically found that with more stable growing environments with respect to factors such as temperature and humidity, the higher the EC can be maintained. The key is to balance the nutrient supply to avoid causing stress to the plant through over or under feeding. Whilst experimenting with varying EC levels the best indication is the plants response and remember that some plants are less tolerant to higher EC levels than others.

When considering nutrient reservoir sizes smaller tanks will fluctuate in EC much more than larger ones. As a general rule the larger the tank holding volume the more stable the EC of nutrient solution will be. When mixing the

nutrient solution try to allow at least 10 litres of nutrient solution for every plant growing in the system. If practical we suggest you try to allow 20 litres of nutrient solution for each plant in your system. It is a very common mistake to overplant the system. When plants are small it may seem that there is plenty of room for growth but as they grow towards maturity the whole system can quickly become overcrowded. The plants then compete for available resources including light, CO_2, and nutrients.

Overcrowded growing systems give rise to tall plants with lower yields than those grown in properly allocated spaces. So when planning your system bear in mind the future needs of your plants when fully mature. More plants DOES NOT mean greater yields. For example, if the reservoir holds 100 litres of nutrient solution, with each plant needing a recommended nutrient volume of 20 litres, then the maximum available resource in terms of nutrients from your reservoir will sustain 5 plants at maturity. Demanding more than your reservoir can deliver results in major swings in both EC and pH which require constant adjustment.

The pH of the nutrient solution is an essential factor that should be monitored in all methods of hydroponic growing. Plants are able to absorb nutrients from the nutrient solution between the ranges of pH 5.0 to 6.8. Outside this range nutrient uptake is reduced. By running the nutrient solution pH within this range growers ensure nutrients are always available to the plant. Experience will dictate the fine-tuning of the nutrient solution pH to obtain the best results from the system. It is important to remember that the pH will fluctuate in a growing system as nutrients are removed, however as long as the nutrient solution pH remains within the operating window of 5.5-6.5 it should not be adjusted. Daily adjustments are not typically necessary and it should only be adjusted if it continues to rise or fall. The buffers used in all *HYDRoToPS* nutrients

will keep the pH stable and within the correct range during the working life of the nutrient solution.

Consistently renewing the whole nutrient solution every four days dramatically improves crop quality and yield, especially when the nutrient reservoir volume is small. Even with larger reservoirs regular changes characteristically give better results.

In summary of the general principals of nutrient solution management:

- *Set the EC of your solution to suit your plants needs and stage of growth.*
- *Monitor the EC and adjust as necessary on a daily basis.*
- *Follow the "feeding on demand" formula when adjusting your EC up or down.*
- *Run a lower EC when temperatures are high.*
- *Use the largest nutrient reservoir you can allowing a minimum of 10 to 20 litres of nutrient per plant.*
- *Change your nutrient solution at least once a week or twice if the reservoir is small.*
- *Do not reduce the EC by adding plain tap water unless your tap water is soft.*
- *Use air stones/lines in your reservoir and growing medium to oxygenate the roots.*
- *Keep the solution temperature below 20 °C. At all times.*

4.3. Nutrient Management in Re-circulating Systems

4.3.1 NFT / Bubbler Systems

This system of nutrient solution management for hydroponic systems was developed by *HYDRoToPS* between 1996 and 2000 and was first published in 2002. This method is intended as a guide but has been proven over many years of application. As experience is gained you may choose to adjust the EC and pH values of the solution to suit the type of plant being grown. Some species have a lower tolerance to a high EC (high nutrient level) than others: as a general rule of thumb when the plants are growing fast the EC of the nutrient solution should be run as high possible. This applies unless the EC is rising as the volume in the reservoir falls, or the plants are beginning to show signs of stress resulting from overfeeding.

Whilst this guide is written for the management of an NFT system the principals can be easily transferred to bubbler pots of ebb and flow systems.

All products mentioned in the guide below can be found discussed in more detail in Section 5.0.

Step 1. Young plants and cuttings which have recently rooted should be watered from the top of the growing block or pot at a rate of 50 ml to 100 ml of nutrient solution at least twice daily until a good root system can be seen from the bottom of the block/pot. The used nutrient solution should be allowed to drain freely from the container and should not be reused. Do not allow the blocks or pots to sit in drained nutrient solution.

The strength of the nutrient solution should be set at an EC between 0.8 to 1.1 in soft water areas and 1.1 to 1.4

in hard water areas. Where the background EC of your water source is 0.7 or more it is better to set the EC of the solution a little higher to 1.5 or 1.6. If set lower than this, the quantities of calcium and magnesium in very hard water will be over supplied and be out of balance in ratio to the other elements supplied by the nutrient. This can lead to problems with potassium uptake later in the plant's life.

When supplying young plants at a high EC, great care should be taken to ensure that high salt levels do not damage the delicate root system. To prevent this from happening water the plants more often and maintain low light levels until the young plants are well established. The roots can be damaged when salts build up in the growing block or pot as the plants remove water, so the more frequently the plants are watered with solution the better the young plants will cope with the higher EC levels.

Step 2. Once a good root system is seen emerging from the bottom of the growing block/pot, the plants may be placed on the NFT or bubbler system. Fill the reservoir to the correct level and add *Grow* nutrient or a *Grow/ Head Start* blend until the EC is between 1.3 to 1.5 in soft water areas and 1.4 to 1.6in hard water areas. Begin circulating the nutrient solution making sure it reaches the root system of each plant. Always add *Root Stimulator* to your nutrient solution as directed on the bottle and as advised in the *HYDRoToPS biOpOnic* feeding schedule. *Root Stimulator* will ensure rapid root development of a healthy thriving root system. As mentioned previously, a good root system is essential to producing a bountiful harvest. We also strongly recommend using *Bactivator* throughout the life of your crop.

Allow the nutrient solution to circulate to the plants for one full day and check the nutrient volume in the reservoir. If the solution volume has fallen by 10% or more, check

the EC of the solution. It may take a few days for the plants to remove a significant quantity of water from the reservoir. Check reservoir levels daily until the plants have removed 10% of the original volume of solution. If the EC has risen from the original level by more than 2 to 3 points (0.2 to 0.3 EC), the nutrient strength is too high and water should be added to reduce the EC by 0.1 or 1 point. This process should be repeated daily. If the EC remains set as the solution volume decreases, the nutrient solution is at the correct strength. Remember the less fluctuation in the growing environment the easier it is to maintain a steady EC.

Once you have arrived at the correct EC for the plants stage of growth it is a good idea to completely change the reservoir especially if you have added a lot of water during this initial period. This is highly recommended in hard water areas. If air temperatures are high within your growing environment, always begin with a lower EC and increase gradually until the correct EC level is established in line with the environmental conditions

Step 3. Once the root systems of the plants have developed and begun to spread into the nutrient flow, the plants will uptake more nutrients and water. As this happens you should notice changes in the EC of the nutrient solution contained in the reservoir. The EC should now be decreasing as the solution volume falls on a daily basis. This is because the plants need for food and water is increasing as the plants grow. In this situation you can begin to increase the EC in the reservoir by one or two EC points *i.e.* from 1.4 to 1.5 or 1.6. Each day as you test and refill the system, adjust the EC of the solution making sure that the EC is not rising as the volume in the reservoir falls. As the plants grow, you can continue with this process until a maximum EC of 1.8 to 2.0 is reached. This should be considered a maximum EC during periods of vegetative growth.

Make sure that you change the nutrient solution at least every 4 to 7 days throughout the complete cycle, setting the EC at the correct strength each time. Changing the nutrient solution every 4 days is preferred, especially if your tank volume is small. Regular changing of your nutrient solution leads to increased yields.

Step 4. Once the plants move into the flowering or fruiting stages of development, change the nutrient solution and renew with a solution made from *Bloom* nutrients. If following the *HYDRoToPS* feeding schedule blend Grow and *Bloom* nutrients as directed in the table for a smooth transition to the fruiting stage. Begin by setting the EC between 1.8 to 2.0, again monitoring the solution EC as the reservoir volume falls. If the EC is falling, increase the EC in the solution by one or two points.

Step 5. As plants approach fruiting the need for nutrients increases exponentially and the EC should be increased in line with the plants needs. Continue increasing the EC over several days until a maximum EC level of 2.2 to 2.3 is reached in soft water areas and 2.0 to 2.4 in hard water areas. If the EC is rising significantly as the solution volume drops in the reservoir, reduce the nutrient strength until the solution EC remains stable.

Using *Top Heavy Crop* during the late growth and early flowering stages and *Triple F* during the bloom phase will increase the number and density of flowers or fruit and will result in increased yields of up to 60%. Be aware when using these products it will be necessary to change your reservoir more regularly as the plants will use significantly more water and nutrients for the additional development. This method requires added work but it can be simply expressed as “the more your plants eat, the fatter your flowers and fruit at harvest”.

Step 6. Once flowers or fruit are reaching full development the plants nutrient requirement decreases and so the EC should be lowered in line with this decrease. By measuring the EC of the nutrient solution on a daily basis it will inform you when this change takes place. The EC will begin to rise constantly in the nutrient solution as the reservoir volume falls. Reduce the strength of the solution in the reservoir to maintain a stable EC. This is best done gradually over a few days to prevent stressing the plants. As the plants approach harvest the EC should be lowered to around 1.3 to 1.5.

Step 7. Seven to ten days before cropping renew the nutrient solution using *biOpOnic Flush*. Whilst often overlooked, the use of Flush is important for the final development of fruit density and quality. The process of flushing helps to remove excess nutrients from the plants, improve the flavour and increase the harvest yield. The EC of the Flush solution should be set between 0.4 to 1.0 in soft water areas and 0.8 to 1.4 in hard water areas. During the flush period do not adjust the pH of the solution but allow it to run at the pH set by the Flush nutrient. You will see the EC rise in the reservoir which is quite normal. It is suggested that the Flush solution is renewed every four days for the best results. For the final two or three days prior to harvest the system can be run on plain water again without pH adjustment. This final period on water only may be extended for up to 1 week if preferred.

Additionally *Top Heavy Crop* is used during the flushing period. This will increase the density of your flowers and fruit and increase the Brix level (sugar content) significantly.

The EC levels suggested throughout are guidelines only however the outlined principle can be applied across a wide range of EC levels and adjusted as experience and environment dictate.

4.3.2 Watering Frequencies

When your plants are young and first planted it is very important to keep the roots moist. This means your growing medium or the spreader mat covering the bottom of the channel should not be allowed to dry out. Usually it is enough to turn on your irrigation pump once every 2 to 3 hours for approximately 15 minutes during the initial stages after transplanting. This will encourage the roots to grow from the planting block out into the channel or down into your bubbler pot in search of water and nutrients.

Eventually the roots will form a mat covering the entire channel or filling the pot, but this will take time. As the root system develops increase the frequency of watering. For example a cycle of 15 minutes on 45 minutes off to 15 minutes on 15 minutes off or 30 minutes on 15 minutes off. Whilst the time cycles are a guide only, as the plants grow they will require larger quantities of nutrient solution. Eventually it may be necessary to run the pump constantly; usually when the plants have reached the flowering stage. This is especially important in hot weather.

If you frequently suffer with high air temperatures a worthwhile addition would be a nutrient solution that is chillier to help maintain solution temperatures within the optimum range, thereby increasing oxygen levels and helping to preventing root disease.

It is a good idea to check your root system to make sure the roots are not completely flooded during your irrigation cycles and that when the pump is not running the root mat drains fully. This ensures the roots are not being starved of oxygen by being submerged constantly.

Do not forget your plants need water during the night period too. It is a good idea to water once or twice during this period.

4.3.3 Conditioning the Growing Media

If you are growing in a bubbler pot or an ebb and flow system the media you use, such as expanded clay or diatomaceous clay (*Hydromis* or *Seramis*) will need conditioning prior to first use. There is a wide variation in the quality of expanded clay balls used in hydroponics, however they are all very alkaline (high pH) in nature and will require conditioning before use. Failing to condition your growing media correctly before employment in your growing system will have profound consequences on the stability of the pH at the root zone resulting in a difficult-to-manage system and diminished growth potential of your plant.

Expanded Clay Balls and Diatomaceous Clay

Wash the clay balls thoroughly in tap water to remove as much dust and debris as possible. Fill a large container with Grow nutrients set to an EC of 1.4 to 1.6 with the pH adjusted to 5.0. Soak the clay balls in this solution for three days. Drain the clay balls and discard the soak solution. Make up a new soak solution with Grow nutrients set to an EC of 1.4 to 1.6 with the pH adjusted to 5.5. Soak the clay balls in this solution for a further one to two days.

Again drain the clay balls discarding the soak solution. The clay balls are now ready for use. Even after conditioning, the clay balls may still cause the pH to rise in your reservoir although the swing in pH will be significantly less than in systems utilising unconditioned media.

A similar approach is required with Diatomaceous clay, the only difference being the pH of the conditioning solution should adjusted to between 6.0 and 6.3.

5. HYDRoToPS biOpOnic Nutrients

The principles behind the *HYDRoToPS biOpOnic* nutrient range and its use are taken directly from knowledge of your plant's natural biochemical processes. The nutritional needs and chemical processes within a growing plant change drastically during the life of a crop and the *HYDRoToPS* approach to growing reflect this important yet often overlooked observation.

When the *biOpOnic* nutrient range was first conceived in 1998 this understanding was foremost in our mind. Each stage of growth requires a different nutritional and biochemical approach for optimal plant performance. However a plant's nutritional needs do not suddenly change with each successive phase of its life. Changes in nutrient demand occur gradually. The *biOpOnic* range is designed to supply the demands of these subtle changes without causing stress to your plants. Each part of the nutrient range has been developed to be mixed with the previous one, achieving a gentle altering nutrient profile that reflects your plants needs throughout its cycle.

The *biOpOnic* range is presented as two individual yet interlinked parts:

biOpOnic Nutrient Concentrates: Soft Water, Area Specific, and Custom Formulations.

biOpOnic Additives and Bio stimulants: Universal root function enhancers, microbial root inoculation, microbial floral stimulants, foliar nutrition, and flowering boosters.

biOpOnic Nutrient Concentrates are formulated using both refined mineral and organic components designed to allow your crop to assimilate the correct balance of nutrition without excessive use of chemical nutrient salts. Not only is this better for your plants but also for our environment. Our *biOpOnic* Additives and Bio stimulants compliment your plant's changing needs throughout

each stage of your crop. Plants require more than a good staple nutrition source to achieve their true potential. So our *HYDRoToPS biOpOnic* Additives have been created to supply the necessary bio-chemical links essential for improving growth and flowering, allowing you to get exceptional results time after time.

We highly recommend the weekly use of *Bactivator* in your nutrient tank up to the flushing period. *Bactivator* is the foundation of the *biOpOnic* Nutrient Programme, supplying the necessary microbes, enzymes, catalysts and organic stimulants to encourage a balanced living ecosystem at the root zone. It is common knowledge that a well developed root system results in increased nutrient uptake and more favourable growth rates. The addition of *Bactivator* ensures maximum nutrient assimilation whilst improving your plant's natural defence systems against fungal infections and pest attacks.

We also recommend flushing with *biOpOnic Flush* at the end of the fruiting period. Whilst often overlooked, using our *biOpOnic Flush* will markedly INCREASE crop yield in addition to improving flavour and quality.

5.1. Approaches

Whilst in previous publications from *HYDRoToPS* our products have been listed in order of product use from start to finish of the complete growing cycle. We propose three different approaches to using our products depending upon the growers experience, whether this be the beginner or budget grower (Simple Approach) to the intermediate grower (Enhanced Approach) to the experienced grower looking for the definitive yield and harvest (Complete Approach).

The Simple Approach: The basic recommended product range to give you the best result when maintenance, time

and budget are the most significant factors. If you are new to *HYDRoToPS* this option provides the perfect first steps to becoming familiar with our products and the results you can achieve. This approach guarantees pleasing results with room to expand by undertaking the Enhanced or Complete approach at a later time.

The Enhanced Approach: The enhanced approach extends the Simple Approach utilising all the products used during the simple approach with the addition of *biOpOnic Root Stimulator* and our legendary *Triple F* flowering enhancer. This approach gives way to greater yields and quality without increasing a grower's workload dramatically and provides excellent value for money compared to the benefits you will see in terms of crop yields.

The Complete Approach: For the discerning grower. Combining all of our available products, this approach has the addition of *Top Heavy Crop*, *biOpOnic Leaf* and *Flower Feed* over the Enhanced Approach. The addition of these three products to your nutrient program will produce results able to delight even the most experienced grower. Further increases in yield, combined with greater sugar content, product density, and flavour can be achieved.

Each of our products are designed to fulfil a specific task and have been tried and tested for over 15 years by *HYDRoToPS* technical staff and experienced growers throughout the country. We only manufacture the things you need and nothing more.

Included within the description of the products are full instructions on how to use them and the workings behind them. At the end of the section you will find a comprehensive growing schedule chart based on your chosen approach and growing method whether this is hydroponic or coco.

Product	Simple Approach	Enhanced Approach	Complete Approach
Bactivator	✓	✓	✓
Root Stimulator		✓	✓
Head Start	✓	✓	✓
biOpOnic Grow	✓	✓	✓
biOpOnic Bloom	✓	✓	✓
Floral Boost	✓	✓	✓
Triple F		✓	✓
biOpOnic Flush		✓	✓
Leaf Feed			✓
Flower Feed			✓
Top Heavy Crop			✓

5.2. Simple Approach Nutrient Program

To undertake the Simple Approach Nutrient Program the following products are required:

Bactivator
Head Start
biOpOnic Grow
biOpOnic Bloom
biOpOnic Floral Boost

5.2.1 biOpOnic Bactivator

Bactivator is a 100% organic bio-stimulation and the natural foundation of a healthy hydroponic, coco or soil growing system. By naturally recreating the conditions found in good, rich, organic topsoil, *Bactivator* offers unrivalled bio-stimulation leading to enhanced compact vegetative growth and the potential for profuse flower and fruit production later in the cycle. Bio-stimulation is seen in nature as the symbiotic or mutually beneficial relationship between bacteria, fungi and the root system of their host plant. The colonisation at the root zone by these beneficial microbes directly stimulates cellular function and root growth in your plants.

Bactivator also provides a natural microbial defence system to resist fungal infections such as *pythium* and *phytopythoria* by removal of their food sources, which in turn prevents the fungal infection taking hold. Having a strong symbiotic root relationship with these essential beneficial microbes also ensures your plant has a greater resistance to pest attack.

Bactivator is supplied as two components: the first is a unique mixture of over 40 carefully selected and cultured beneficial microbes and fungi in a latent state specially blended with amino acids and extracts of Fulvic and Humic acid. The blend will remain stable in this state indefinitely until activated. Once activated, the microbes in *Bactivator* attach themselves to the root hairs and take the waste products from root functions and convert them into usable plant nutrients to ensure nutrients and oxygen remain at optimal levels during all stages of crop growth.

The second component is a liquid blend of plant hormones, enzymes, amino acids and microbial catalysts designed to stimulate root function and sustain the microbial culture during the initial stages of inoculation.

Bactivator should be added to the nutrient reservoir on a weekly basis to maintain good microbial balance at the root zone. *Bactivator* can also be used in conjunction with any nutrient concentrate to enhance biological activity at the root zone. However, for the best result we recommend using as part of the complete *HYDRoToPS biOpOnic* nutrient programme.

If you have not used *Bactivator* before and experience a root infection in your crop, we recommend double dosing with (activated) microbes only. Activate the microbes (2 doses in 500 ml tepid/25 °C water and allow to stand for 30 minutes) If you can aerate the microbial solution before use this will increase its effectiveness of combating the root infection. Add immediately to the nutrient solution but DO NOT add the liquid catalyst in this application.

One final caveat when working with natural microbial products such as *Bactivator*, *Triple F*, and *Top Heavy Crop* is that it is essential that you DO NOT use hydrogen peroxide (H_2O_2) with these products. Doing so will severely restrict the effectiveness of the microbes. H_2O_2 based products are used to add oxygen to the nutrient solution as well as acting as a disinfectant The carefully selected blend of micro organisms in our products not only keep your root free of potential infections they also regulate the availability of oxygen directly at the root zone where it is needed most.

Whilst avoiding peroxide based products, it is also advisable to maintain the temperature at the root zone between 17 °C to 19 °C. During the summer months it is not always possible to maintain your nutrient temperature within this range, however our microbial products will continue to work up to a temperature of 30 °C without reduced effectiveness.

Using hydrogen peroxide during the summer months to add oxygen and to prevent root disease is a common

practice. Whilst this may work to some degree, considering a nutrient chillier is an effective alternative.

Some companies advocate that microbes in hydroponic systems perform no useful function. We know they do! *HYDRoToPS* were the first company to research microbial symbiosis in hydroponics in 1996. Ask any *HYDRoToPS* grower if *Triple F*, *Bactivator* or *Top Heavy Crop* work! Try these products for yourself and see the difference, you won't be disappointed

biOpOnic Bactivator is available in 10 & 25 dose packs. (Each dose treats 50 litres of nutrient solution)

5.2.2 biOpOnic Head Start

biOpOnic Head Start is a combined full spectrum nutrient concentrate developed with the biochemical and nutritional needs of young plants and cuttings in mind. Your plant's potential yield is governed by the nutritional profile supplied during this critical stage of development. Feeding your plants correctly balanced nutrients in their early stages sets the feeding pattern needed to assimilate nutrients fully during the critical final growth and flowering period, and has a direct effect on final crop yields. Again *HYDRoToPS* were the first company to introduce products specifically designed for this crucial stage in your plants life.

So why should I use a product like *Head Start*?

Growers often use a half-strength nutrient solution during the propagation and early stages of growth. This strategy is not ideal and can lead to problems later in the growing cycle. There are two main issues associated with this practice, the first being trace elements are under supplied (by half) and second that the nutrient profile of the major elements are not at the correct ratio. In response

to this the plant adjusts its biochemical processes and restricts its growth rate to the amounts of trace elements available.

In young plants and cuttings, the balance of phosphate and calcium are critical to good root development. Young plants need to develop an extensive root system quickly to have the best possible chance of producing its maximum harvest.

As the nutrient strength is increased, even though the nutrient levels are increased, the plant is unable to adjust its intake for several weeks. This will lead to deficiencies and poor flower set around the fourth week of the fruiting period.

biOpOnic Head Start considers the above points and is balanced for the needs of young plants, cuttings and plants with a low EC requirement. Both trace elements and major elements are supplied at the correct levels and ratios to ensure a smooth and stress-free transition from the propagator to your hydroponic system.

biOpOnic Head Start builds on the foundations of *Bactivator* and *Root Stimulator* to promote the establishment of your young plants with balanced root growth, compact branching and good foliar development.

biOpOnic Head Start is available in 1 litre and 5 litre for soft water and area specific formulations.

Here are a few tips to aid propagation using *biOpOnic Head Start*. Although growers following our Simple Approach may not be using *biOpOnic Root Stimulator*, we have included its use here. We know how effective it is in the propagation process and its use is highly recommended throughout the life cycle of your plants.

5.2.3 Propagation Tips Using biOpOnic Head Start and biOpOnic Root Stimulator

Step 1. To each litre of water add 5 ml – 10 ml of *biOpOnic Root Stimulator* with 7 ml of *biOpOnic Head Start*. Adjust the pH to 4.5 – 5.5 with pH Down.

Step 2. Soak the Rockwool rooting cubes in this solution overnight. This will condition the alkaline Rockwool to a stable pH of between 5.5 and 6.5. This process is essential for getting the best results. For growers using peat pellets we suggest the same levels of both *Root Stimulator* and *Head Start* but only reduce the pH to 6.0 to 6.3 if required. When correctly mixed will give a solution pH very close to this range.

Step 3. Drain cubes thoroughly and squeeze as much solution as possible from each cube without damaging its structure.

Step 4. Make a small hole in one corner of the rooting cube with a small implement such as a match or cocktail stick. Do not use the large hole in the cubes centre since placing the cutting at the edge of the cube will ensure good oxygen levels and assist with quicker rooting.

Step 5. Soak or dip the cut end of your cuttings in *biOpOnic* Rooting Hormone or your chosen rooting powder or gel for 5 seconds.

Step 6. Insert the cutting gently into the cube and place in a propagator at a temperature of 25 °C. A 25 mm layer of wetted Hydromis or perlite should be used in the base of heated propagators to increase humidity, which prevents drying of the rooting cube and subsequently potential root damage. Do not let rooting cubes dry out. Check daily and dip bottom 2 mm of the Rockwool cube in /*Root Stimulator* solution adjusted to pH 6.0 to 6.3 (if required).

Step 7. Mist cuttings twice per day with water until roots begin to show. Always chose the cuttings which root first since these will have more vigour and produce healthier plants.

Step 8. Check cuttings after the fifth day for signs of rooting.

Step 9. Once roots are visible feed cuttings daily with a solution of: 10 ml/litre *biOpOnic* Root Stimulator with10ml/litre *biOpOnic Head Start* by dipping the bottom 2mm of the rooting block into the solution, allowing it to rise halfway up the cube by capillary action (Set the EC between 1.0 to 1.2 for soft water and 1.2 to 1.4 for hard water). Do not allow the rooting cubes to dry out.

Step 10. Mist cuttings daily with a solution made up as directed in step 9.

Step 11. Once good root development is observed transplant into the growing block. Growing blocks should be conditioned before use in the same manner as rooting cubes described in Sections 1 and 2. Remember this is a critical step to obtaining the best results.

Step 12. Feed the transplant 50 to 100 ml of *biOpOnic Root Stimulator/biOpOnic Head Start* (made up as indicated in section 9) every 12 hours from the top of the rooting cube until root development is seen below the growing block. Equal amounts should be given to each plant, and the intervals between feeds should be consistent. This will ensure even development in the cuttings.

When the time comes to move your plants into the growing system or at the “hardening off” stage you may begin to increase the EC of the feed you are giving to your plants. By mixing *biOpOnic Head Start* and *biOpOnic Grow* formulation together in the ratios given in the Growing Schedule you will have fine control over

both your nutrient strength and the profile of your nutrient solution. Doing this ensures a smooth transition from cutting to young plant without stress and avoids nutrient issues. The results later on will reward you for the extra effort you have taken.

5.2.4 biOpOnic Grow

Progressing from the propagation phase sees a dramatic change in the nutrients required by your plant. To satisfy the plants new demands we have formulated *BiOpOnic Grow* to ensure that full nutrient assimilation is maintained during this transitional period. *BiOpOnic Grow* is designed to be mixed with *BiOpOnic Head Start* as previously described, to make this change stress free for the plant. *BiOpOnic Grow* is balanced to encourage the establishment of strong branches, abundant foliage, and profuse flowering sites.

Just like any of our products *BiOpOnic Grow* has been developed to encourage maximum nutrient assimilation since during the growth phase larger nutrient uptake relates directly to increased yields when harvesting. Growers using *Top Heavy Crop* as part of the complete growing schedule will see amazing growth and vigour, shortening the period required for vegetative growth whilst maintaining yields. Using *Top Heavy Crop* will seriously increase the number of flowering sites.

Rate of use is 3 – 4 ml of both A & B to each litre of water. With young plants mix with *Head Start* to gradually increase you EC moving to *biOpOnic Grow* once your plants are fully established.

biOpOnic Grow is available in 1 litre, 5 litre and 25 litre two part sets. Formulated for hydro or coco.

5.2.5 biOpOnic Bloom

Moving into the flowering period sees the introduction of *BiOpOnic Bloom* which is designed to be mixed with *BiOpOnic Grow* during the change from grow to bloom. The plant's nutritional requirements only change slowly over the first three weeks of the bloom period, so by supplying nutrition reflecting these changing needs your plants nutrient assimilation profile remains high, producing greater yields and healthier plants. The process of getting the correct nutrient profile during the changeover is as follows:

Bloom week one: 75% *biOpOnic grow* – 25% *biOpOnic bloom*.

Bloom week two: 50% *biOpOnic grow* – 50% *biOpOnic bloom*.

Bloom week three: 25% *biOpOnic grow* – 75% *biOpOnic bloom*.

Bloom week four: 100% *biOpOnic bloom*.

Rate of use is 3 – 4 ml of both A & B to each litre of water. During the flowering and fruiting period the EC is increased gradually in line with the plants nutritional uptake. Please see *biOpOnic* feeding schedule for full details.

biOpOnic bloom is available in 1 litre, 5 litre and 25 litre two part sets. Formulated for hydro or coco.

5.2.6 biOpOnic Floral Boost

During the fourth to sixth or seventh week of the bloom period, the plant's nutritional uptake continues to rise before eventually reaching a climax. During this time the ratios of nutrient assimilation change rapidly. *biOpOnic Floral Boost* works by enhancing the levels of phosphorous, potassium, magnesium and ammonical nitrogen needed for profuse setting of flowers and fruit.

The solution pH will fall during this stage, which allows greater assimilation of phosphates required for profuse fruit and flower production.

In the later stage of the bloom period the rate of nutrient assimilation falls and the use of *BiOpOnic Floral Boost* is discontinued. The EC of the nutrient solution is thus lowered to allow the plants to take up water and nutrients in balance without resistance. If the EC in your reservoir rises more than 0.2 to 0.3 points when the plants have removed 25 % to 35 % of the reservoir volume, we suggest your EC is probably a little too high. We recommend monitoring your solution carefully from the sixth week of fruiting and reducing the EC as needed to maintain a stable EC in your reservoir. Where air temperatures are high it is better to run a slightly lower EC to prevent stress from excess salt levels. There is no set guide for the ideal EC since your plants genetics and growing environment will dictate the correct level. Careful control of the nutrient EC during this stage is critical for high flower and fruit density.

Currently a number of PK boost products are available on the market indicating that formulating their product by weight rather than volume is one of the keys to increased yields. A number of these products also contain Plant Growth Regulator (PGR) chemicals that act to manipulate the plant in order to increase its potential yield. It is important to be aware that most of these included PGR chemicals are not intended for use with food crops or have not been classified/licensed for use and could have potentially unforeseen health implications to the end user. We are proud that *HYDRoToPS Floral Boost* first released in 2002 has always been formulated by weight rather than volume and it contains no PGRs.

When used with *Top Heavy Crop* and *Triple F*, all of which also contain NO PGRs, the end result has left even the most experienced growers impressed.

A commonly accepted myth in hydroponics is flower boosters and PK products are responsible for greater yields. It is true that during the flowering cycle these products will give the greatest benefit. However this only happens when your plant has maximised its period of vegetative growth, producing as many flowering sites possible. Less than optimal vegetative growth will only result in less than optimal flowering.

To take this into consideration *HYDRoToPS* products are designed for use from propagation through to the third week of the flowering cycle to ensure optimal growth for bumper future flower and fruit development whilst shortening the growing cycle without compromising your yields.

biOpOnic Floral Boost is available in 1 litre, 5 litre, and 25 litre.

5.3. Enhanced Approach Nutrient Program

The Enhanced Approach builds upon the excellent building blocks of the Simple Approach Program. In the Enhanced Approach Nutrient Program we introduce three additional products designed to boost plant performance and see further increases in yields.

To undertake the Enhanced Approach Nutrient Program the following products are required:

Bactivator

Head Start

biOpOnic Grow

biOpOnic Bloom

biOpOnic Floral Boost

biOpOnic Root Stimulator

Triple F - Fully Formed Flowers

biOpOnic Flush

5.3.1. biOpOnic Root Stimulator

The foundation of any growing system whether it be hydroponic, coco or soil is the development of a large, fully functional root system. To grow a good shoot capable of bearing bountiful flowers or fruit requires a high quality root system. Whilst *biOpOnic bactivator* is the foundation of any exceptional root system *biOpOnic Root Stimulator* supplies the energy and organic stimulants to build on this foundation with outstanding results. It also distinctly increases nutrient uptake when used and it is common knowledge that the greater the nutrient intake the greater yield at harvest. The development of a good working root system is essential for the best possible yields. By adding *Root Stimulator* to your nutrient program you will immediately see the results in terms of vigour and growth in your crop.

Stage of growth	ml per litre
Propagation Period	5 – 10 ml
Transplant / Hardening Off	5 – 10 ml
Grow period	10 – 15 ml
Bloom week 1 and 2	10 ml
Bloom week 3 and 4	5 – 7 ml

biOpOnic *Root Stimulator* combines plant-extracted bio-enhancers, vitamins, co-enzymes, silicon and fractions of fulvic/humic acids blended in an organic complex for easily assimilation and rapid effect to achieve its results. It also provides the perfect balance of hormones and stimulants to encourage root growth, and to stimulate essential biological processes within the roots. Root efficiency is directly related to potential crop yield. The more efficient the root mat, the greater the plant's ability to take up water, nutrients, and oxygen from the nutrient solution or soil.

Root development reaches a maximum during the 3rd to 4th week of flowering. *Root Stimulator* should be added to the nutrient solution weekly from the propagation stage through to the end of the 3rd or 4th week of the flowering period, and used as part of a Combined Foliar Feeding Programme (see Combined Foliar Feeding Programme Section *5.4.2*.

As a bonus, *Root Stimulator* also increases your plants' resistance to environmental stress and high temperatures, a useful additional benefit during the warmer months of summer.

biOpOnic *Root Stimulator* is available in 1 litre, 5 litre and 25 litre.

5.3.2. Triple F - Fully Formed Flowers

The now legendary *Triple F* was developed by *HYDRoToPS* in 2003, rapidly proving itself to be the best floral stimulation and booster product available in all growing media. Tested and refined for over 13 years, *Triple F* has consistently shown its high level of effectiveness.

What is Triple F?

Triple F is a 100% natural microbial based fruit and flower booster delivering up to a 50% yield increase without the use of Plant Growth Regulator (PGR) chemicals. Since we released *Triple F* 10 years ago a number of flower boosting products have been released using PGRs to induce extra flowering. Whilst many of these products produce extra flowers and increased yields, we believe nature offers the best solution every time. Many of the PGR's used in boosters today MUST be licensed and are for use on non-food crops ONLY. There is a reason for these regulations to be in place as many of these additional chemicals are known to have carcinogenic effects and may be linked to the development of serious medical conditions.

HYDRoToPS never has and never will use PGRs or other dubious chemical additives that may cause harm.

Triple F is a totally natural 100% bio-organic product that gives you singularly spectacular yield increases, whilst avoiding all potential PGR associated health risks. *Triple F* is totally safe to use in all crops and is kind to the environment. Why would you choose to use anything else?

How does Triple F work if it contains no chemicals?

The natural symbiosis between the microbes contained in *Triple F* and your plant's root system triggers flowering site receptor signalling and directly increases nutrient assimilation at the correct time to produce profuse fruit and flowers, with increases in yield of up to 50%.

So what is in Triple F?

The first component of *Triple F* is a blend of beneficial micro organisms that work in harmony with your chosen growth medium and your plants root system to enhance nutrient uptake.

The second component is an organic microbial catalyst that initially acts as a food source for the microbes and then as a complexing agent, which is required during the developing symbiotic relationship between the micro organisms and your plant's roots.

In essence *Triple F* has no health risks, no environmental dangers, just great results every time!

Available in 125 ml (treats 250 litres), 250 ml (treats 500 litres) and 500 ml (treats 1000 litres)

5.3.3. biOpOnic Flush

Towards the end of the flowering and fruiting phase nutrient intake slows down, yet there are considerable reserves of nutrients left in the plant sap. If these levels are not depleted during the final development of the fruit before harvest the resulting crop will have a bitter metallic taste. The term flushing can be misleading; a better term would be "finishing" since it is essential that any nutrients not used by the plant are removed before harvest. This is exactly what *biOpOnic Flush* does by supplying the correct ratio of enzymes, organic plant hormones and catalysts to enable your plants to process as much of the excess nutrient as possible and remove any surplus prior to harvest.

HYDRoToPS were the first nutrient manufacturer to introduce the concept of flushing to the world of hydroponic growing back in 1999. Many users have claimed that our *biOpOnic Flush* is one of our strongest products. Using *biOpOnic Flush* increases the density of your final product significantly and should be considered as important as using a PK booster to enhance flower production. We also recommend using *Top Heavy Crop* during the flushing period. This increases the Brix (sugar content) levels within your product and results in an

extremely dense final product with an enhanced aroma and sweet flavour.

The correct time to begin the flushing process is when the intake of the nutrient has slowed and your plants, are running at a reduced EC level. This usually occurs around two weeks prior to harvest. 1 to 2 weeks prior to harvest change the nutrient tank using *biOpOnic Flush* in preference to our *biOpOnic Bloom* nutrient.

The EC of the solution supplied is not critical and can be set between 0.4 to 1.0 in soft water areas and 0.8 to 1.4 in hard water areas.

During the first three days of the last week before harvest we recommend mixing a fresh nutrient tank using *biOpOnic Flush* at half the normal dosage rate without adjusting the pH. During the last four days before harvest the tank may be run on tap water only without any adjustment of the pH. By extending the end of the fruiting period by one week using *Flush*, crop quality and yield will increase significantly.

Flush Application Rate:

10 days before harvest 5 -10 ml per litre.

7 days before harvest 5 ml per litre.

4 days before harvest plain tap water only.

biOpOnic Flush (hard water, soft water, and area specific formulations) is available in 1 litre, 5 litre, and 25 litre.

5.4. Complete Approach Nutrient Program

To undertake the Complete Approach Nutrient Program the following products are required:

Bactivator

Head Start

biOpOnic Grow

biOpOnic Bloom

biOpOnic Floral Boost

biOpOnic Root Stimulator

Triple F - Fully Formed Flowers

biOpOnic Flush

biOpOnic Leaf Feed

biOpOnic Flower Feed

Top Heavy Crop

The Complete Approach Nutrient Program is the most considered approach to maximising your results with *HYDRoToPS*. During this program our whole range is utilised to give maximum performance. The additional products allow for the fine-tuning of your plant nutrition to build the strongest floral set possible.

Foliar feeding is a well established practice in commercial horticulture and for good reason. It supplies essential nutrients to the crop when nutrient demand is at its greatest. In an ideal situation with the root zone performing at 100% efficiency the need for foliar feeding may not be necessary. We have mentioned the importance of a well developed, fully functional root system as being key to obtaining the best results. Nevertheless when the temperature in the growing space is hot or the nutrient solution temperature is not in the ideal range foliar feeding can be of great benefit.

HYDRoToPS Foliar Feeds are tailored to your plants requirements at different stages of the growing cycle and are designed to supply essential nutrients and bio-stimulants to ensure your plant's use of nutrients from the root and foliar feeding are maximised to their full potential.

5.4.1. biOpOnic Leaf Feed

During vegetative growth when plants are growing vigorously, nutrient assimilation via the roots may fall short of your plants needs. This is often due to environmental stress. To overcome this *biOpOnic Leaf Feed* may be used as part of a Combined Foliar Feeding Programme (see below).

biOpOnic Leaf Feed encourages extensive branch formation and enhances the effectiveness of *Top Heavy Crop* for a greater potential yield. In addition to balanced nutrition *biOpOnic Leaf Feed* supplies essential amino acids, enzymes and growth enhancing stimulants for biochemical balance within your plants.

To make up a full strength *Leaf Feed* solution, mix 100ml of the concentrate with 900 ml of tepid tap water. Allow it to stand for 30 minutes and then spray the plants foliage lightly to the point of runoff. With cuttings and young plants we recommend mixing *biOpOnic Leaf Feed* at half strength (50 ml to 950 ml of water) until plants are established and transplanted onto the growing system Do not mix with any other products and store both the concentrate and any made up solution away from strong light.

It is critically important not to spray your plants in full light as this may scorch the developing foliage. Always spray your plants during darkness, preferably one hour before daylight. If your plants are photoperiod sensitive use a green light source/bulb to prevent disruption of the day length.

Four Day Combined Foliar Feeding Programme:

Day 1 Foliar *Leaf Feed* solution.

Day 2 pH adjusted water (adjusted to 6.5) plus 10 ml of *biOpOnic Root Stimulator*.

Day 3 Foliar *Leaf Feed* solution.

Day 4 pH adjusted water (adjusted to 6.5) plus 10 ml of *biOpOnic Root Stimulator*.

Repeat during vegetative growth period. See feeding program for further information.

biOpOnic Leaf Feed is available in 1 litre and 5 litre.

5.4.2. biOpOnic Flower Feed

During the first weeks of the flowering period your plants nutrient requirements increase significantly. It is critical that these needs are fully met at this stage, as it is at this point where crop potential is predominantly dictated. *biOpOnic Flower Feed* is designed to supply the correct ratio of nutrients for the transition from vegetative growth to full flower development combined with the essential bio stimulants necessary for maximum nutrient absorption. *biOpOnic Flower Feed* also supplies the grounding to allow *Top Heavy Crop* to complete its function of increasing the number of final flowering sites in preparation for a bumper harvest.

To make up a full strength *Flower Feed* solution, combine 100 ml of the concentrate with 900 ml of tepid tap water. Allow to stand for 30 minutes and then spray the plants' foliage lightly to the point of runoff. Do not mix with any other products and always store both the concentrate and any made up solution away from strong light.

Again it is critically important not to spray your plants in full light as this may scorch the developing foliage. Always spray your plants during darkness. If your plants are photoperiod sensitive use a green light source/bulb to prevent disruption of the day length. Do not mix any other products when applying foliar feeds this will increase the likelihood of damage to your plants.

Four Day Combined Foliar Feeding Programme

Day 1 Foliar *Flower Feed* solution.

Day 2 pH adjusted water (adjusted to 6.5) plus 10 ml of *biOpOnic Root Stimulator*.

Day 3 Foliar *Flower Feed* solution.

Day 4 pH adjusted water (adjusted to 6.5) plus 10 ml of *biOpOnic Root Stimulator*.

Repeat during the early flowering period. See feeding program for further information.

biOpOnic Flower Feed is available in 1 litre and 5 litre.

5.4.3. Top Heavy Crop

The final product in this guide is *Top Heavy Crop*. Having been in research and development now for over five years, we believe this to be one of the finest products we have yet developed and we like to think we have kept the best (for now) till last.

The common misconception is that flowering enhancers, boosts, stimulants, and PK additives are the best method to increased yields. This is not the complete story when it comes to dense heavy products at harvest as the complete story begins much earlier in the plant's life cycle. The foundations of the best harvest possible are based on a fully functional root system as mentioned

multiple times during this guide, along with the correct nutritional balance at all stages of the plant's life, a well managed growing environment, and the number of flowering sites each plant can develop. It is with this last point that *Top Heavy Crop* proves itself beyond any flower booster product available.

And just like *Triple F*, *Top Heavy Crop* is based totally on tried and tested 100% organic microbial approach to yield increase and so contains no harmful PGRs.

The strongest structure in engineering is the triangle. Now *HYDRoToPS* have completed our trilogy of microbial based products to give you outstanding yields whilst enhancing, protecting, and developing your root system.

Bactivator is the foundation on which your plants are established.

Top Heavy Crop supplies the power and structure to encourage maximum flowering potential.

Triple F – Fully Formed Flowers supplies the building blocks to complete the cycle producing dense fruit and flowers with a plentiful harvest.

Top Heavy Crop is supplied as two parts:

The first part is a microbial blend which performs two important functions.

The first benefit is an increased lateral rate of vegetative growth with shorter internodes and increased branch formation. The second is a flowering site trigger signal response to stimulate the production of an increased number of flowering sites, which means added flowers and fruit at harvest. A supplementary effect of this microbial interaction with your plant's leaves and root system is an increased Brix (sugar content) content in your final product resulting in denser fruits combined with rich aroma and taste.

The second component is an organic microbial catalyst, which initially acts as a food source for the microbes and then as a specific complexing agent, which is required during the developing symbiotic relationship between the micro organisms, your plant's roots and leaves.

Top Heavy Crop is used during the two weeks before flowering and until you begin using *Triple F*. It is also used during the final flushing period. You will immediately see the power of *Top Heavy Crop* at work once you begin using it as part of your nutrient program.

In summary *Top Heavy Crop* encourages:

Shorter vegetative growth period without loss of yield.

Increased flowering site production.

Denser fruit and more abundant flowers at harvest.

Richer flavour and aroma from your favourite fruit and flowers.

Available in 125 ml (treats 250 litres), 250 ml (treats 500 litres), and 500 ml (treats 1000 litres).

6. Your Growing Environment

Understanding the environment in which you grow your plants and how to manage it within a specific set of parameters is paramount to obtaining the best results. In this section we shall discuss the issues related to the most favourable growing conditions as well as steps to take when maintaining it.

The conditions needed for sustaining healthy plant growth can be divided into three categories. These are known as the Root Environment, Photoperiodic Environment, and the Shoot Environment. When each of the environmental variables within these categories

are set correctly yield improvements will follow. All variables discussed in this section are essential and more importantly they are all interlinked.

The Root Environment = Root function and conditions at the root zone.

The Photoperiodic Environment = Lighting and how best to use it.

The Shoot Environment = The air temperature, humidity, air exchange and air movement.

7. The Root Environment

Defined as the root zone of a plant, this is without question the foundation of your plants and is the origin from which all growth is driven. The development of a plant without a strong, well established root system can be likened to building a house upon sand.

There is an undeniable relationship between the size and weight of the root system and the total weight of the plant when it comes to harvest. Simply expressed the greater the mass of the root system the greater the amount of fruit or flowers the plant will produce at harvest. Thus by understanding the needs of the root system and maintaining a healthy, productive environment at the root zone, we ensure our plants can function at maximum efficiency to reach their highest yield output.

The roots of a plant assimilate three critical components to growth:

Water

Nutrients

Oxygen

To emphasise the importance of the root zone, if your plants are showing symptoms of stress or nutrient deficiency you should always examine the condition of the plant's roots first. Whilst this may not always be the reason for the problems you are experiencing it should always be the first aspect to rule out since most nutrient problems are due to root problems, environmental issues, or poor nutrient solution management, NOT THE NUTRIENTS THEMSELVES.

7.1. Oxygen Levels and Drainage

As a plant's root system matures it develops in such a way that various areas of the roots or root mat grow to perform different individual functions for the plant. These roots can be classified as *Water Roots* and *Air Roots*.

Water Roots develop in the lower section of the root mat or growing medium where water saturation is at its highest. Their function is to absorb water and nutrients required from the nutrient solution.

Air Roots are located in the upper areas of the root mat where oxygen levels are higher and water saturation is reduced. Their function is to withdraw oxygen needed for photosynthesis within the plant.

It is essential to appreciate both of these two types of root to apply effective management of the root system as a whole.

For example, when the ratio of oxygen to water decreases in the area occupied by the Air Roots, or there is a lack of oxygen at the root zone due to high nutrient solution, temperatures, problems with root function and plant growth readily occur. If Air Roots are constantly submerged in water the plant is unable to obtain sufficient oxygen for the root system to work successfully. The plants

nutrient assimilation is quickly affected and non-specific or multiple nutrient disorders begin to show as symptoms on leaves. Eventually this will cause damage to the root system and allow root pathogens and diseases to take hold *e.g.* pythium which is the major cause of root rot.

Here the take home message is “roots starved of oxygen = plants starved of food and energy = poor growth rates”.

In re-circulating systems like NFT it is essential that the nutrient solution flow rate is sufficient to supply a steady flow beneath the root mat. Where flow rates are too high or system drainage is badly implemented, the Air Roots can become easily flooded. It is advisable to check your roots regularly to make sure you are supplying the plants with a happy medium in respect to nutrient solution to prevent possible root problems.

In media based systems, such as drip irrigation onto rockwool, coco, or clay pebbles, do not let the roots sit in stagnant pools of water. Ensure roots are allowed to drain freely at the end of each irrigation cycle. Direct aeration of the root mat can have a drastic positive effect on both root function and plant growth rates.

HYDRoToPS have worked closely over the years with Jim Green (ex. Nugreen Hydroponics and now of Urban Jungle Garden Supplies in Birmingham) with systems designed specifically to increase oxygen concentrations at the root zone.

Jim developed the first bubbler system in 1999 now commonly known as “The Birmingham System”. *HYDRoToPS* have been building on and refining this system now for over 10 years. The system incorporates the supply of oxygen to both the nutrient solution in the reservoir and directly to the root system itself. Whilst many other bubbler type systems have been introduced we firmly believe Jim’s system to be the most effective

for maintaining a healthy root zone and thus yielding the greatest results.

One possible problem that can occur in bubbler systems is poor drainage within the growing pot. Most systems are supplied with insufficient drainage holes in the pot. To combat this we strongly recommend drilling supplementary 6 mm holes in the base and the lower 2/3rds of the pot wall. Whilst seen as added effort to create a sieve like construction, the additional drainage will yield much better results.

7.2. The Nutrient Solution

The nutrient solution supplies the plant with two essential components: water and nutrients. The nutrient solution is directly connected with the root environment and we strongly advise revisiting the section on Nutrient Management in Section 4 on page 17.

The temperature of the nutrient solution has a strong impact on the function of the root zone. When roots are cold the metabolic functions (internal workings) of the plant slow and growth is restricted or in severe cases ceases completely. We suggest that nutrient solutions should be maintained at temperatures between 18 °C to 20 °C for optimal growth. In addition to this, fluctuations in nutrient solution temperature should be kept to a minimum. When adding new nutrient solution or water to the system, steps should be taken to ensure it is at the same temperature as the existing nutrient solution in the reservoir. If you add cold nutrient solution it would shock the plant's roots and would require considerable time to recover. This has the knock-on effect of reducing the roots efficiency to assimilate required oxygen, nutrients, and water reducing the growth rate of your plant.

A separate nutrient mixing tank is preferable in which pre-mixed nutrient solution set to the correct strength (EC) are stored. If possible this should be heated to the same temperature as the working nutrient solution and constantly aerated with an air pump and diffuser, for example air stones.

Remember to check your nutrient pump regularly and clean the filters. When using our *biOpOnic* nutrients the organic material residues can obstruct the filters, though regular cleaning will avoid potential problems. This simple check requires minimal effort in relation to the exceptional results our products offer when compared to straight chemical salt based products.

As discussed earlier, the strength (EC) of the nutrient solution affects root function. The EC must be set to reflect the plants needs during each stage of growth and should not undergo large changes. It is important to observe this at all times including changes in nutrient temperature as plants require a consistent environment to thrive.

8. The Photoperiodic Environment

The Photoperiodic Environment refers to all matters related to light. As we know light is essential to all plants as it is the energy source plants harness in order to grow. Since it is such an important factor in plant life it is worthy of further discussion in relation to your own growing environment.

When we use the term Photoperiodic Environment, we are referring to the quantity of light received by the plants and the even distribution of light across the growing canopy. In the case of grow lights this is often used to describe the area of growing space effectively covered by each light.

All plants require a minimum amount of light to undertake photosynthesis; the process of combining carbon dioxide and water to make sugars which are used by the plant to grow. Each species of plant has a different optimum light requirement and the effect of light changes can readily be seen in nature. Under low light levels plant growth is slow, such as in early Spring but as light levels increase, rapid growth and flowering will be observed in the Summer months.

Fast growing annual plants usually have a high light requirement.

Some plants prefer moderate levels of light. These plants are often found in their natural setting growing in shaded conditions. Some tropical foliage plants which grow naturally in the rain forests of South America only require low light levels. This type of plant has evolved in the Photoperiodic Environment of the forest floor where very little direct light reaches the plants living there. In comparison tropical plants which grow in high mountainous areas such as Morocco, South America, or the Himalayas usually require light conditions similar to their natural habitat. This is also true of plants growing in Africa and some parts of Asia. These type of plants require moderate levels of light when young, high levels of light during growth and even higher levels of light during flowering.

Growing indoors usually requires the use of artificial lighting systems. These can be fluorescent lights designed for plant growth or sodium and metal halide lamps, which give higher levels of light output. In the English climate growing indoors is usually the only way such plants can be grown successfully.

It is important that the grower is aware of the correct light requirements for the plants and how the choice of light will cause problems with temperature levels in the

growing area. This is more important in summer due to naturally higher temperatures.

Lights not only emit light but heat also, and this needs to be carefully considered when choosing your lights. Fluorescent lights emit very little heat but do not have a high light output (intensity). Due to these factors fluorescent lamps are great for propagation and establishing young plants during their early stages of growth.

Discharge lights with metal halide or sodium lamps discharge far greater levels of light output but also increased levels of irradiated heat. The lights most commonly used in horticulture are rated at 250 watt, 400 watt, and 600 watt. These types of lamps are better suited to growing well established plants through to maturity.

Occasionally 1000 watt lights are used; however a higher rated output is not necessarily best. This is because of the accompanying increase in heat emitted. As a result of the increased heat output these light have to be mounted at a significantly larger distance above the crops than there lower rated counterparts (*i.e.* 250, 400, and 600 watts). A general rule of thumb to remember is that as you move away from a light source, the intensity of that light source declines dramatically. This factor renders 1000 watt lights as one of the least efficient means by which to provide lighting within your growing environment.

8.1. Getting the Best from your Light Source

To extract the best results from your light source it should be mounted as close to your plants as possible; though this distance has to be balanced to avoid burning the plants flowers or leaves by being too close. As a guide the air temperature directly between the lamp and the growing plant should be no more than 2 °C to 3 °C higher than the temperature amongst the growing plants.

The employment of air cooled reflectors can be particularly helpful in reducing the mounting distance between your plant and light source whilst reducing problems associated by burning from heat build up. Remember radiated heat from the lamp still needs to be considered when using air cooled lights and deciding the optimum mounting height of the reflector. Another consideration when using air cooled reflectors is the design of the reflector itself. Whilst you may be able to mount the air cooled light 15 cm from your plant without an optimally designed reflector the light distributed from the light will only cover a small area with any degree of efficiency.

Analysing lighting requirements in more detail has shown that the maximum light output from a light is within 30 cm of the bulb (the light source). At a distance of 60 cm from the bulb the light output is reduced to 25%. The physical law governing light intensity is called the "*Inverse Square Law*", and is expressed below in both its mathematical and verbal forms.

$I = 1/d^2$

Light intensity (I) = 1 divided by the distance from the light source (bulb) squared (d^2).

Knowing this simple equation can allow us to calculate the effectiveness of our light source. The traditional way of representing this has been given below for completeness.

Thus if we wished to calculate the light intensity (I) at a distance (d) of 30 cm (this is written as 0.3 metres in the calculation below) from the light source the calculation is :

$I = 1/(0.3 \times 0.3)$

$I = 11.11$ Therefore the light output = 11.11 (100%)

If we increase the distance from the light source to 60 cm (0.6 metres):

I = 1/(0.6 x 0.6)

I = 2.77 Therefore the light output = 2.77 (25%)

This shows that by doubling the distance from 30 cm to 60 cm between the bulb and plant, light transmission drops to 25% or ¼ of its original value.

A more practical example can be demonstrated using a 400 watt sodium lamp which has an output rated at 56,000 lumens. Whilst watts are a fairly familiar unit of power (often given the symbol "*W*"), a lumen (often given by the symbol "*lm*") is a measure of the total amount of visible light given off by the bulb.

In our example, if we mount the light at 30 cm above the growing plants, then transmission is at its maximum efficiency. Because of this we can assume 100% light transmission. Thus 56,000 lumens will transmit to the plants' surface.

If the light was then mounted at a height of 42 cm from the plant, the light intensity (*I*) would be 50% and thus only half the total number of lumens would light the plant surface, in this case 28,000 lumens.

If the light was finally mounted at a height of 60 cm from the plant, the light intensity (*I*), as we already know would be 25% and thus ¼ of the total lumens would light the plant surface, in this case 14,000 lumens.

Again these calculations prove that doubling the distance between the light source and the plants reduces the intensity of light to only 25% of its previous value.

The important message to take from these calculations is that it is typically a better choice to utilise lower wattage light sources (*e.g.* 250 watt). This is because they generate less heat allowing them to be mounted closer

to the plants without causing burning related damage. By being able to mount them closer you maintain maximum light transmission intensity. Alternatively if you prefer to use higher wattage light sources air cooling is vital to achieve the same result.

There is extra benefit from employing a greater number of lower wattage lights (*e.g.* 250 watt) compared to fewer higher wattage lights (*e.g.* 600 watt) since it is more efficient in terms of plant growth and energy used to employ a greater number of smaller wattage lights mounted closer to the plant canopy, rather than a few larger wattage lights to cover the same area. The theory comes from observations that plants respond far better indoors in terms of growth when light is available from several points (several lighting units). Plants growing under a single light will all grow towards the source, creating competition for available space and light. With several points of light (several lighting units) covering an area, plants will develop more evenly in the space and will remain compact and squat rather than stretching for the light.

Young plants should not be placed directly into a high light regime straight from the propagation area. Plants from the propagation area are accustomed to the much lower light levels of that environment and must be introduced to higher light levels gently. When introduced to higher light levels too fast young plants show signs of stress, poor root growth and nutritional deficiencies.

Young plants with immature root systems are also unable to take in enough nutrients and water to cope with the photosynthetic demands of the plant (how plants use light to make the energy and subsequently grow). A direct consequence of this will be a movement of mobile elements, such as nitrogen, from the older foliage to the newer growth. Young plants must have a very well

developed root structure before you consider placing them under high intensity lighting or planting out into a hydroponic growing system

The relationship between light levels and growth was first introduced at the beginning of Section 3 where in nature young plants initiate during the lower light levels of early Spring, produce leafy growth during the moderate light levels of late spring and early summer, and then flower or develop fruit during the high light levels of Summer. We can imitate these natural light changes through careful regulation of artificial light levels.

The introduction of adjustable output digital ballasts for lighting systems can be a great advantage to growers wishing to increase light levels according to your plant's stage of growth. One added benefit from their use allows the light intensity to be reduced in periods of hot weather. Of course, reduced light output will create less heat.

Since most indoor growers grow in small areas, light selection is decisive in extracting maximum yields from your plants. When choosing the most productive method of lighting for your indoor area it is wise to consider as a general rule of thumb; "*the greater the light intensity, the greater the yield*" . This holds true providing no other variables such as temperatures, disease and pests, or poor environmental control are not an issue.

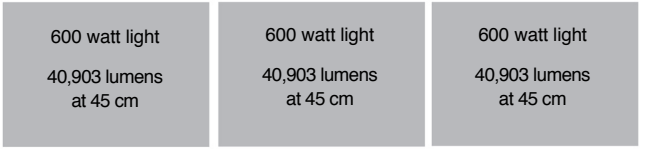
When considering the most effective method to light an area, for example 1.5 metres by 1.0 metres, there are many options available, though the grower's budget and ability to control the environment will be influencing factors. In the following sections several ways of meeting your lighting requirements are considered.

As a final note, we need to consider the amount of power used to run the lighting system, the heat generated, the efficiency of the lights/mounting height over the plants

and the evenness of the light distribution. For the sake of economy and maximum illumination we shall limit the power consumption between 1 kW and 1.8 kW.

8.1.1. 600 Watt Lights

In our example area we could choose to use 3 x 600 watt lights (see diagram below). 600 watt lamps have a very high lumen output (92,000 lumens) but need to be mounted 45 cm above the plant canopy. Using our calculation from Section 8.1 at this mounting height only 44.46% of the maximum light potential is available (40,903 lumens). Mounting at a lower height to improve light efficiency would be possible with air cooled reflectors but the reflectors would not cover the area evenly in terms of light distribution with an equal light intensity across the area.



Area covered per light	= 0.5 m x 1.0 m (40,903 lumens)
Power consumption	= 1.8 kW
Total lumen output	= 122,709 lumens over 1.5 m^2
This equates to 68,172 lumens per kW of power.	
This can also be expressed as 81.81 lumens per cm^2.	
Three points of light offering moderate illumination consistency.	

8.1.2. 400 Watt Lights

We may also choose to use 4 x 400 watt lights (see diagram below) mounted at 30 cm above the plant canopy. In warm weather this may not be possible due to heat issues. The reflectors at this mounting height may not give entirely even distribution of light so in reality it will be necessary to mount the lights at 40 cm to achieve an acceptably even light coverage. Here using air cooled reflectors will not benefit light distribution but will allow lower mounting heights for increased light intensity if desired.

400 watt light 31,500 lumens at 40 cm	400 watt light 31,500 lumens at 40 cm
400 watt light 31,500 lumens at 40 cm	400 watt light 31,500 lumens at 40 cm

Area covered per light	= 0.5 m x 0.75 m (31,500 lumens)
Power consumption	= 1.6 kW
Total lumen output	= 126,000 lumens over 1.5 m^2
This equates 78,750 lumens per kW of power.	
This can also be expressed as 84 lumens per cm^2.	
Four points of light offering acceptable illumination consistency.	

8.1.3. 250 Watt Lights

In order to achieve the most advantageous illumination in our area of 1.5 m x 1.0 m we could use 6 x 250 watt lights. Whilst this approach requires the most lights we shall demonstrate this is possibly the most efficient and

economical way of lighting our example growing area. The lights can be mounted at 30 cm above the plant canopy giving maximum light output per light and the most even light spread from six sources (points).

250 watt light 33,000 lumens at 30 cm	250 watt light 33,000 lumens at 30 cm	250 watt light 33,000 lumens at 30 cm
250 watt light 33,000 lumens at 30 cm	250 watt light 33,000 lumens at 30 cm	250 watt light 33,000 lumens at 30 cm

Area covered per light	= 0.5 m x 0.5 m (33,000 lumens)
Power consumption	= 1.5 kW
Total lumen output	= 198,000 lumens over 1.5 m^2
This equates 132,050 lumens per kW of power.	
This can also be expressed as 132 lumens per cm^2.	
Six points of light equating to excellent consistency of illumination.	

When we look at the above lighting analysis we can easily see how the 6 x 250 watt light array works out as the most effective, efficient, and cost effective light for use in indoor growing. The area covered at the optimum mounting height is 50 cm x 50 cm. This is an ideal unit when calculating the lighting requirements when designing a growing space. Further to this a growing area of 1.0 m x 1.0 m (1 m^2) can be optimally illuminated by 4 x 250 watt lights.

9. The Shoot Environment

The Shoot Environment refers to any aspect related to the air contained within the growing space. If we consider the environment from a plant's point of view, a Shoot Environment that is stable and does not fluctuate dramatically is a very desirable thing. Plants growing in a stable environment are able to reach their true genetic potential. This is because plants naturally control their internal biochemical and growth processes in response to the environment they are growing in. Where the environment is stable and free from major fluctuations, growth rates and yields are phenomenal.

The primary factors to consider are:

Ventilation (air exchange)

Stratification Control (air movement)

Air Temperature

Relative Humidity

Carbon Dioxide Concentrations

Managing the above variables in the Shoot Environment correctly will provide you a fast track to healthy plants that yield their maximum potential.

The aforementioned variables should not be considered as isolated variables to control, since each one exists in a mutual relationship with the other variables. It is imperative all variables of the Shoot Environment and those of the Root Environment and Photoperiodic Environment are addressed with equal control and importance to extract the greatest performance from your growing environment. Like a weak link in a chain, if one of these variables is not sufficiently controlled or resides outside acceptable limits the chain will break and plant growth will be diminished in some respect.

9.1. Ventilation (Air Exchange)

Ventilation (airflow in and out of the growing area) performs several essential functions in controlling and managing the shoot environment. Air exchange can be used as a means of regulating air temperatures, relative humidity, and the supply of carbon dioxide needed by plants as part of the photosynthetic process. Ventilation is normally achieved by the use of fans, one to draw air into the growing area (in-take fan) and one to extract air from the growing area (exhaust fan). These fans are switched on together and are usually controlled by a time switch, thermostat, or environmental controller. The ventilation system should be capable of totally replacing the air in the growing area in the shortest time possible.

Well-designed systems should be capable of exchanging the total air volume in the growing environment within 3 to 5 minutes of being switched on. When establishing a ventilation system it is suggested that you install fans rated more powerful than required. By taking this precaution you ensure the fans are being used below their maximum air exchange rates which does not stress or overwork the system. If you chose to fit a speed control to the fans you can lower/raise the extraction rate as required to aid in temperature control. This will result in a longer working life of the fans.

The size of the fans you choose depends on the air volume of the growing space in cubic metres (m^3).This is calculated as follows:

Volume in cubic metres (m^3) = length (L) x width (W) x height (H) in meters (m).

For example, if the dimensions of the growing space are as follows we are able to calculate the volume of the room in m^3.

L = 3.0 m, W = 2.5 m, H = 2.0 m

Volume = 3.0 × 2.5 × 2.0

Total Volume = 15 m^3

We would advocate that you install fans able to replace the total volume of air in the growing space 30 to 35 times per hour. Fans are generally rated by the volume of air they can move in a given period of time, which is typically expressed as m^3 per hour. It is an important consideration that even if you are only utilising a small segment of your growing area it is essential that the fans installed are sufficiently powerful to replace the total air volume in the growing space.

Using the above example we are able to calculate the required air exchange rate and thus the total fan rating.

A room volume of 15 m^3 × 35 air exchanges per hour = 525 m^3 per hour.

This is the air exchange rate required, or the amount of air your fans need to be able to move each hour to maintain optimum air movement

The fans should be rated to exchange this volume of air plus an additional 15 to 20% to allow for loss of efficiency when using flexible fan ducting. If there are many bends in the ducting or you are using reducers or filters, a 30% "*over rating*" of the fans should be considered for the most efficient ventilation.

Taking in this additional requirement, our calculation continues as follows:

Total volume capacity of fans required = air exchange rate + added efficiency percentage calculation (20%)

Total volume capacity of fans required = 525 + 105 (105 = 20% of 525)

Total volume capacity of fans required = 630 m^3 per hour

The installation of two fans, with a combined rating able to exchange this volume of air every hour is common place, although frequently a grower will install a marginally more powerful intake fan to draw fresh air into the growing space. By doing this, a mild positive pressure will be created in the growing space making it more difficult for insect pests to become established in the growing space. If temperature levels are likely to be a concern you may choose to install two fans of a higher rating than theoretically required.

Fan manufacturers produce simple and efficient in-line fans with several rated outputs. These fans can be fitted with filters and other accessories as desired. The common sizes vary between 100 mm and 315 mm. The smaller the fan, the lower the air flow. Manufacturers also supply the air movement rating for each fan size so you can choose the correct fans quite easily. Remember if you incorporate a filter or reducer to your fan system it will decrease its efficiency and this will have to be taken into consideration in your calculations.

Long runs of air ducting will also reduce the air movement efficiency and can soon add up, which is why we always recommend choosing fans with a larger capacity than you think you will need. When budgeting for your growing system do not try to save money on reducing your ventilation. The correct air exchange is indispensable to getting the best from your crop. Below is a generic table for fans of a given output. There will be differences between manufacturers, however this table will offer you a guide as to the volume of air each size of fan is able to move.

100mm	125mm	150mm	150mm	200mm	250mm
Low	Low	Standard	High	High	High
175 m^3 per hour	250 m^3 per hour	420 m^3 per hour	680 m^3 per hour	750 m^3 per hour	950 m^3 per hour

In our theoretical growing space we needed to exchange 630 m^3 per hour using two fans. Looking at the table above we see a 150 mm standard fan and a 125 mm fan working together will be capable of achieving this level of air exchange with minimal excess. Thus a better choice would be a 150 mm high output fan and a 150 mm standard fan. You may even choose to use a 200 mm standard fan and a 150 mm high output fan if temperature is a potential issue. The larger rating fan should always be used to draw air into the room if you desire positive pressure.

When mounting the fans ensure the air intake fan is discharging fresh air into the lower portion of the growing space near the floor and the exhaust fan draws air from the top portion of the growing space.

9.2. Stratification Control (Air Movement)

Until now we have stressed the importance of air flow through the growing space. Even with good, regular air exchange the Shoot Environment requires further air circulation to prevent stratification of the air into layers or strata inside the growing space. Commonly growers use oscillating fans to circulate the air inside the growing space. This will only partially prevent stratification, so is neither the best nor most efficient method.

We suggest the use of a dump fan system within the growing area in place of an oscillating fans. A *dump fan system* is simply one or two small in-line fans with ducting connected on both the inlet and exhaust ends. A 100 mm fan is ideal for this purpose. The fan is usually mounted on a wall; the inlet ducting is placed directly beneath or at the same level as the hydroponic system drawing air from the floor space. The exhaust ducting is mounted to discharge the air directly over the reflectors down onto the plant canopy.

The incorporation of a dump fan system not only circulates the air in the growing area, it also prevents the air pockets between the light bulbs and plants from becoming too hot. This effect obviously allows the grower to have the light units nearer the growing plants and secure the maximum efficiency from their lighting rig.

A common misconception amongst growers is plants need to be moved during air movement. This is not so. As the downward flow of air under pressure from the dump fan system prevents pockets of stale, humid air forming in the plant canopy with minimal plant agitation. When plants are moved excessively by fan draught, the cell walls in the stems are damaged slightly. When this occurs the plant needs to redirect energy and resources into repairing this damage when this energy could be used in growth promotion. Air movement within the growing area should merely disturb the micro-environment around the leaves of the plants and nothing more.

Incorporation of a dump fan system ensures a first-rate distribution of carbon dioxide amongst the plants. When carbon dioxide enrichment is used in the growing area, the carbon dioxide, being denser than oxygen will descend to the floor of the growing area. When operating a dump fan system in the growing area, you ensure that the settled carbon dioxide is constantly transferred to the top of the plants and allowed to fall again, under gravity, showering the foliage as it falls. It is our view that carbon dioxide enrichment is an environmentally questionable matter and you should seriously consider if you need to use it. Good air exchange in your growing area supplies all the carbon dioxide your plants require for healthy growth.

Often growers report considerable increases in yield just by the addition of a dump fan system inside the growing area. The cost of installing a dump fan system is minimal when compared to achieving larger yields more consistently.

9.3 Air Temperature

The air temperature in your growing area needs careful thought. Bearing in mind that plants prefer little or no variation in environmental conditions, it makes perfect sense to control air temperatures as accurately as possible as many of the internal biochemical processes of a plant are governed by external temperature.

Where a plant is grown in conditions of fluctuating temperatures, the rates at which internal chemical reactions occur within the plant are constantly altering in response to these temperature changes. This results in an inefficient use of energy, which your plants could invest into growing. Simply put temperature variations are highly likely to reduce growth and thus crop yield.

Temperature levels both during the day and night cycles need to be jointly considered. Warm day temperatures and lower night temperatures will result in plants stretching during the dark period. When using indoor lighting systems this can make your lighting less efficient since short, squat plants make more proficient use of the light as the light will penetrate further down the plant. Conversely tall, thin plants only receive sufficient light levels at the top of the plant. Where possible, plant heights should be controlled to remain within the optimum depth of light penetration from the lighting system. One way to achieve this is to maintain consistent temperatures during the day and night period or indeed one or two degrees higher during the night period.

During the day, the radiant heat generated by the lighting system maintains warm temperatures in the area. During the dark period where the lights are deactivated, temperatures will naturally fall. A small electrical fan heater or oil filled radiator controlled by a timer and thermostat correctly set to the desired

temperature will ensure temperatures between periods remain consistent.

There are certain stages of the growing cycle, where a high humidity is desirable, such as during the vegetative growth and early flowering or fruiting period *(see Section 4.4)*. When this is the case, a slightly warmer night temperature is desirable.

When questioning the ideal temperature in a growing area there is no simple answer. Good temperature levels are closely related to carbon dioxide concentrations in the atmosphere *(see section 4.5)*. However a good range is between 22 °C to 26 °C. Where carbon dioxide enrichment is used and especially under high lighting conditions, air temperatures between 26 °C to 30 °C are preferred. Temperatures above 30 °C should be avoided unless the grower is experienced and a good environmental control system is in place. At these elevated temperatures you must be wary that internal chemical processes inside the plant can slow and eventually stop. You may choose to ensure the ventilation system installed in your growing area can be controlled using a thermostat to ease temperature management during both day and night periods.

As previously stated, variations in temperature will effect plant growth responses. One factor often overlooked by growers during the ventilation cycle, is the factor of cold air from outside the area entering the growing space and quickly lowering the air temperature around the plants. This will not only shock plants but can reduce their growth rate whilst they adapt. Where possible, ensure your inlet fan is drawing in fresh air from a warmed area and not directly from the outside. During the winter months, this problem can result in drastic loss of vigour and growth rate seen in the plant.

9.4. Relative Humidity

Relative humidity refers to the amount of *water vapour* present in the environment. Many problems seen in indoor growing environments can be traced to a poor understanding of the effects of humidity on plant growth.

Temperature and humidity are interrelated factors in the Shoot Environment. Warm air will hold less moisture than cold air. So when night temperatures in the growing area fall markedly below the day temperature, the relative humidity will rise accordingly. An environment that is too humid, especially where air temperatures fluctuate can promote the development of moulds.

Too low a humidity level, especially when plants are young can have a severe effect on nutrient uptake and transpiration rate. Where this is the case, leaves are often seen curling upwards along the leaf margins. The ideal level of humidity for plants is between the range of 55% and 70% under normal growing conditions.

When plants are small and recently planted into the system, a humidity of 70% during the day is optimal. This level of humidity is maintained during the day as the plants develop throughout the vegetative period and into early flowering or fruiting. With artificial lighting, it may be necessary to use a humidifier to achieve this.

As the plants develop into full fruiting, the day humidity can be lowered to 55% - 60%. Humidity levels during the night should be continuously maintained at 50% - 55%.

Where high daytime humidity is maintained, it is necessary to increase the night air temperature a few degrees above the day temperature. This will lower the night humidity to the desired range. The installation of a de-humidifier can be considered to combat this problem. A simple relay switch over system can be constructed to

run a humidifier during the day and a de-humidifier during the night.

A note on fans: it is a good idea to run your ventilation system during the dark period. If you have a fan speed controller you can turn the fan rate down or set your fans to come on intermittently with a timer. Plants require oxygen during the dark period and it is essential this is replenished by exchanging the air in your growing space regularly.

9.5. Carbon Dioxide (CO_2)

Carbon in the form of carbon dioxide (*CO_2*) gas is an essential plant nutrient. Plants fix the carbon from the atmosphere in which they are growing and use it to produce sugar, an essential source of plant energy.

In the atmosphere around us there are between 300 and 450 parts of carbon dioxide in every million parts of air (*ppm*), which equates to an atmospheric concentration of 0.03% to 0.045%. This is referred to as the background CO_2 concentration.

Plant growth rates are directly linked to the availability and quantity of CO_2 in the Shoot Environment. If CO_2 levels fall, plant growth will slow, where CO^2 levels are increased or maintained at the background level, plant growth rates are maximised. If there are no other limiting factors in the environment, maintenance of these levels of CO_2 will result in marked growth rates.

Plants will only assimilate CO_2 during the day whilst at night they assimilate oxygen. In light of this CO_2 enrichment should only be used during the day but should not be turned on immediately at first light. You should allow for 20 – 30 minutes for activation of the plants metabolic rate before starting enrichment.

We are strong advocates against the use of CO_2 enrichment. If you choose to use CO_2 enrichment, to use it to full effect light levels, air temperature, relative humidity, and root function must all be synchronised to enable your plants to use additional CO_2 effectively. Since all other factors are rarely in total harmony we urge you to work without CO_2 enrichment. If your air exchange rates are good there will always be sufficient CO_2 available for maximum growth even under intensive lighting conditions. Evidence for this derives from the complicated links between each aspect of the environment, which we shall now look in further detail.

9.5.1. The Light / Carbon Dioxide Link

There is a connection between light levels and the quantity of CO_2 present in the air surrounding the plants. In order to process more CO_2 than is already present in background levels, the plant must increase the rate of photosynthesis. With higher light levels plants are able to achieve greater CO_2 assimilation. However higher light intensities without a balanced supply of carbon dioxide from good air exchange will slow the plant's internal mechanisms, and potentially cause damage to the plant. As a general rule a high light intensity = higher photosynthetic rates = higher carbon dioxide requirements supplied by good ventilation or enrichment should you choose = increased growth rate.

Superb results can be achieved without the need for specialist CO_2 enrichment systems. If there is regular air exchange from a well designed and installed ventilation system there will always be sufficient CO_2 available to support vigorous growth at all times.

As considered growers we need to be aware of the impact our growing has on the environment. Increased

levels of CO_2 added to the environment is not beneficial to the planet or ourselves.

We ask “If you don’t need it, why use it?”

9.5.2. The Temperature / Carbon Dioxide Link

Temperatures in the growing area need to be high for effective use of enhanced levels of carbon dioxide above the background level. Generally a plant’s metabolic rate speeds up as temperatures in the shoot environment increase, providing there are no other limiting factors. The higher metabolic rate allows the plant to use higher levels of CO_2.

As a guide where enrichment systems are used, the higher the level of enrichment, the higher the required temperature in the growing area. However the maximum temperature in the growing area should be no more than 30 °C. Temperatures above this are detrimental to plant growth.

9.5.3. The Humidity / Carbon Dioxide Link

Relative humidity levels need to be considered when employing CO_2 enrichment. 80% RH should be maintained during the day cycle during vegetative growth and 70% during early flowering stages. When vegetative growth stops further CO_2 enrichment will not be effective and the humidity levels should be reduced to 50%. During the final stages of crop development it may be useful to lower the humidity to between 35% and 40%. This will help reduce the risk of mould infections in your flowers and fruit.

Glossary of Terms

Acidic - The term acidic is used to describe a solution or chemical compound, which has a pH value lower than pH 7.0.

Alkaline - The term alkaline is used to describe a solution or chemical compound, which has a pH value greater than pH 7.0.

Assimilate - To take nutrients and other compounds into the plant.

Background EC - The conductivity of the water supply being used. The greater the amount of dissolved minerals present in the water supply, the easier it will conduct electricity.

Bi-carbonates - Bi-carbonates are alkaline compounds dissolved in the water supply; usually calcium bi-carbonate or magnesium bi-carbonate. These compounds determine the hardness of the water supply. Soft water supplies are low in bi-carbonates and hard water supplies are high in bi-carbonates.

Buffering capacity - The ability of a solution to withstand changes in pH. The buffering of a nutrient solution is governed by the amount of residual bi-carbonates present once nutrients have been added and by the choice of chemicals used in the formulation of the nutrient concentrate.

Buffers (pH) - pH buffers are solutions with a known pH. Usually found as pH buffer 4, 7 and 10. They are used in the calibration of pH meters and should not be confused with buffering capacity.

Conductivity standard - A solution of a known conductivity used to calibrate EC meters.

Custom nutrient - For use in areas not suitable for use with a standard nutrient concentrate. The resulting nutrient solution is balanced nutritionally and pH buffered.

Drip irrigation - Nutrient solution supplied to each plant through an individual feeding tube.

EC or *electrical conductivity* - The rate at which a solution conducts electricity. The greater amount of nutrients dissolved in solution the easier it will conduct electricity. Weak nutrient solutions will have a low EC and strong nutrient solutions a high EC when measured with an EC meter.

EC meter - A special meter used in hydroponics to measure the strength of the nutrient solution (See *PPM/TDS*).

Environmental conditions - The conditions in which plants are grown such as air temperature, air humidity, nutrient solution temperature, oxygen levels at the root zone and air exchange within the growing space.

Fluctuation - Term used to describe marked changes in conditions either in a nutrient solution or in the environmental conditions within a growing area.

Flush - A special technique used during the last weeks of a hydroponic crop to improve crop quality and flavour. Flushing ensures all excess nutrients within the growing plants are used before harvest.

Hormone - A chemical compound usually required in very small amounts to regulate growth responses in plants.

Humidity - The amount of moisture present in the air.

Internode - The region of the stem between two successive nodes.

Irrigation - The supply of nutrient solution to a crop.

Irrigation cycle - Usually a timed cycle of nutrients being supplied to a crop, *e.g.* pump on for 15 mins; pump off for 45 mins.

Media or *medium* - The term used to describe the substance used to contain the plants roots, e.g. rockwool, clay pebbles etc.

Node (nodal point) - The part of a plant stem from which leaves or a branch emerge.

Nutrient concentrate - A highly concentrated solution of nutrients designed to be added to a volume of water to produce a

working nutrient solution. Usually 1 litre of concentrate will make up 200 to 250 litres of working nutrient solution.

Nutrient flow - The amount of nutrient solution delivered each minute to the hydroponic system. Young plants require low nutrient flow rates with the volume supplied being increased as the plants grow towards maturity.

Nutrient solution - A dilute solution made up to the correct strength to reflect the plants stage of growth. In hydroponics, the solution must contain all of the essential elements required for plant growth.

pH - The term used to describe the acidity or alkalinity of a solution. pH values less than 7.0 being acidic and greater than 7.0 being alkaline.

pH down - An acid used to lower the pH of a working hydroponic nutrient solution.

pH up - An alkaline solution used to raise the pH of a working hydroponic nutrient solution.

ppm (parts per million) - This term is used to express the amounts of any element dissolved in a solution. The term *milligrams per litre* is often used in technical publications to describe the same relationship. For example 400 ppm of nitrogen means 400 mg of nitrogen in 1 litre of water.

RH - Relative humidity.

TDS or *total dissolved salts* - The term used to describe the total amount of salts in ppm in a solution. Some conductivity meters are calibrated in TDS. As a conversion factor 1.0 ms (EC of 1.0) is equal to 670 ppm /TDS.

Toxicity - A physiological condition caused by an excess of one or more elements in the plant sap. The effect of the condition often results in plants being unable to assimilate other essential elements through the root system. This will cause symptoms of multiple nutrient deficiencies to occur.

Trace elements - Essential elements needed for plant growth, required in very small (or trace) quantities. Trace elements are essential in the production of enzymes and other biological processes inside the plant. Trace elements are sometimes referred to as micro elements.

HYDRoToPS biOpOnic feeding schedule

The nutrient ratios and EC levels on the product labels and in the feeding schedule are offered as a guide only. Your experience of the plants you are growing will be the ultimate guide. By monitoring the nutrient strength in the tank as the plants remove solution you are able to set the nutrient strength to suit your plants needs.

For the best results change the tank completely every few days. This is important especially if your tank volume is small. When using *triple F* and *Top Heavy Crop* your plants will remove much more solution than usual. Regular changes equal impressive results.

The *biOpOnic* feeding schedule is summarised in the table on the following pages.



HYDRoToPS biOpOnic feeding schedule

	Young Plants	Grow Period Week 1	Grow Period Onwards	Fruiting Week 1	Fruiting Week 2
Root Stimulator	5 - 10 ml	5 - 10 ml	10 ml	10 ml	7 - 10 ml
Bactivator	yes	yes	yes	yes	yes
Head Start	7 - 10ml	7 ml			
biOpOnic Grow		2 ml	3 - 4ml	3 ml	2 ml
biOpOnic Leaf Feed	½ strength	¾ strength	full strength	full strength	
Top Heavy Crop			yes	yes	yes
biOpOnic Bloom				1 ml	2 ml
biOpOnic Flower Feed					full strength
Triple F					
Floral Boost					
biOpOnic Flush					
EC Soft Water	0.6 - 1.2	1.2 - 1.4	1.4 - 1.7	1.5 - 1.8	1.6 - 1.9
EC Hard Water	0.8 - 1.4	1.4 - 1.6	1.6 - 1.9	1.7 - 2.0	1.8 - 2.1
pH Guide	5.5 - 6.0	6.0 - 6.3	6.0 - 6.3	6.0 - 6.3	6.0 - 6.3

Fruiting Week 3	Fruiting Week 4	Fruiting Week 5	Fruiting Week 6	Fruiting Week 7	Fruiting Week 8	Flush Week 9 Week 10
5 - 10ml	5 ml	3 ml	2 ml			
yes	yes	yes	yes	yes	yes	
1 ml						
						yes
3 ml	4 ml	4 ml	4 ml	3 - 4 ml	2 - 3 ml	
full strength	full strength					
yes	yes	yes	yes	yes		
0.5 ml	1 ml	1 - 2ml	1 - 2ml			
						5 - 10 ml
1.7 - 2.0	1.8 - 2.1	1.9 - 2.2	1.7 - 2.0	1.4 - 1.8	1.2 - 1.5	0.4 - 0.8
1.9 - 2.2	2.0 - 2.3	2.1 - 2.4	1.9 - 2.2	1.6 - 2.0	1.6 - 1.9	0.8 - 1.4
6.0 - 6.3	6.0 - 6.3	6.0 - 6.3	6.0 - 6.3	6.0 - 6.5	6.0 - 6.3	6.5 - 7.9

Grower's Notes...



...Have fun!