CHAPTER 4 OTHER ADDITIVES

There are things other than just nutrients and water that can sometimes be added to the nutrient solution, in order to help along plant growth. In some instances these additions may be important.

Introduction

Legumes such as peas and beans will grow optimally in hydroponics utilising the plentiful nitrogen provided in the nutrient solution. While they may also naturally develop the root nodules containing nitrogen-fixing bacteria which soil grown crops form, these are not essential for hydroponic crops. Inoculation of hydroponic systems with mycorrhiza for N fixation and N nutrition is thus not required for hydroponic production of legume crops, however root nodules often form naturally anyway as these bacteria may be naturally present on seed, ion water supplies and in the growing environment.

Manual Home Hydroponic kit. Two bottles of nutrients need mixing to create a complete, balanced solution.

One situation where nitrogen-fixing crops are highly beneficial is with organic hydroponic systems where chemical sources of nitrogen such as calcium and potassium nitrate are not permitted. In these 'hydro-organic' systems nitrogen can be limiting under rapid growth rates. Legume crops, with their ability to obtain additional N through the association with Rhizobium species are thus a good choice for organic systems. While these bacteria do occur naturally in many hydroponic systems, with legume crops in organic systems the plants can be inoculated with the correct species of nitrogen-fixing bacteria which are widely available as microbial productions or incorporated into seed coatings. The root nodules that form on hydroponic legume crops are visible and appear as knobbly, rounded growths which can reach the size of a pea, firmly attached to the root system – these have sometimes been mistaken for root pathogens or other diseases by inexperienced growers, but are a perfectly natural occurrence.

The use of systemic pesticides in the nutrient solution is illegal in many countries and may lead to unacceptable residues in the produce being grown. Due to the fact that many pesticides, fungicides and other agrochemicals used for pest and disease control may react with the elements in the nutrient solutions it is not advisable to use these products in this way. Foliar spray application of pest and disease control products, following label instructions for rates and usage and only applying spray compounds registered for use on the crop being grown must be followed by all growers. In hydroponic systems care also needs to be taken when spraying pest or disease control products onto crop foliage as excess run-off may end up in the root zone and nutrient solution. This can create a contamination issue and may lead to traceable illegal residues in food crops.

Allowable Additives for Hydroponic Nutrient Solutions

A number of different additives and supplements may sometimes be used in hydroponic nutrient solutions. However, it is important to consider the role and functions of such additives before application and to ensure that none of them pose a potential plant toxicity or food safety risk. In solution culture, the addition or organic additives (those containing large amounts of carbon) should be treated with caution as these can provide a food source for microbial life, some of which may not be beneficial. Addition of large amounts of carbon-containing additives can also increase the BOD (biological oxygen demand) of the nutrient solution, thus reducing dissolved oxygen (DO) available for root uptake.

Humates (humic and fulvic acids)

The beneficial effect on plant growth of adding the correct humic substance has been known for a number of decades. These compounds are not only effective in soil grown crops, but also in various potting mixes and hydroponic systems. Application of humic substances to soils naturally low in organic matter, or hydroponic systems, seems to produce the most significant growth enhancement effects. Humic compounds can be absorbed by plant roots and transported to the shoots, thus enhancing the growth of the whole plant. In hydroponic tomato plants, it has been found that humic acid application resulted in higher root fresh weights and dry weights, as well as higher levels of certain mineral elements in the shoots and roots than those plants grown in nutrient solutions without humic acid. This same effect has been found in other hydroponic crops.

Studies on the effects of humic acid on plant growth under conditions of adequate mineral nutrition consistently show positive effects on plant biomass. Humic acids increase soil and plant productivity by enhancing the uptake of essential nutrient elements through chelation and increasing plant growth through their effect on root enzymes and the soil. Both increases in root length and stimulation of the development of secondary roots have been observed for humic acid in nutrient solutions, soils and growing mixes. The stimulating effect of humic acid has been correlated with enhanced uptake of nutrients. Humic acid has also been found to increase photosynthesis in some plant species, thus enhancing the growth of the whole plant. Humic acid has been widely proven to have beneficial effects on plant growth over a wide range of concentrations with application as a soil/media drench, seed soak and nutrient solution additive.

Fulvic acid is one of the many chemical compounds that qualify as humates, and it appears to be more biologically active than humic acid. Fulvic acid has direct effects on membranes resulting in improved transport of nutrients, enhanced protein synthesis, possible plant hormone-like activity, and enhanced photosynthesis. It also has indirect effects such as solubilisation of micro-elements (Fe, Zn, Mn), as well as some macro-elements (K, Ca, P), reduction of active levels of toxic elements, and enhancement of microbial populations.

Humate products are available in a number of different forms for use in hydroponic nutrient solutions however selection of water soluble fulvic acid products is most commonly used in solution culture. Humate additions are typically available as either a water soluble powder or a liquid concentrate ready for dilution and dosing directly into the hydroponic nutrient solution. These products are often incorporated into other organic additives and organic fertiliser concentrates. There is some evidence to suggest that combining humates with other crop bio-stimulates such as seaweed extracts or amino acids can provide further growth benefits, although it is somewhat dependant on the method of application, the concentrations used, and the crop species grown.

Surfactants

Apart from their common use as spray additives and wetting agents, non ionic surfactants have two major potential uses in hydroponic nutrient solutions. The first has been known since the 1960's, which is the fact that non ionic surfactants have the ability to kill pathogen zoospores and control the spread of certain root rot diseases in the nutrient solution. The second is a more recently reported effect of surfactants in boosting plant growth in some species under hydroponic conditions.

The control of disease zoospores in hydroponic nutrient solutions by non ionic surfactants was actually discovered by accident when researchers applied a fungicide containing a surfactant to a hydroponic lettuce crop. It was discovered that the synthetic surfactant in the fungicide was effective in destroying the zoospore plasma membrane, thus reducing the ability of the spores to move and infect plants, eventually killing them. While non ionic surfactants had little or no effect on any other stage of the disease life cycle (which have cell walls rather than plasma membranes), in killing or retarding the zoospores in the nutrient solution the potential for the control of these root infecting pathogens was realised.

Further studies were carried out on a number of different hydroponic crops which were prone to zoosporic fungal disease outbreaks. Most found highly promising results in that non ionic surfactant used at the correct rate could give a high degree of disease control of Pythium and Phytophthora in the nutrient solution. However, while the surfactant could destroy large numbers of zoospores being carried by the nutrient solution, hence prevent or slow the spread of these diseases, it had no effect on plants already infected when the disease was present inside plant tissue. Thus use of non ionic surfactants in the nutrient solution is more of a preventative action rather than curative – it destroys zoospores released by active disease outbreaks and prevents these from infecting new plants.

In order to be effective, the correct rate of non ionic surfactant product needs to be continually maintained in the nutrient solution. When this is achieved growers have reported good results. Many of the newer bio-surfactant products designed for hydroponic use include dose rates on the product label which should be carefully followed. As with most products and compounds available as nutrient solution additives, over-dosing does not give better results. In many cases, it can be quite toxic to the plants. Another issue concerning dose rate is that surfactants are gradually broken down by microbial action over time. Determining how often to re-dose may be difficult and require some trial and error.

There are other issues with potentially beneficial additives growers should be aware of. For example, some growers who found non ionic surfactant useful for the reduction of root rot pathogens such as Pythium also reported foaming in the nutrient reservoir was common, particularly in the first few days after the surfactant was added. Foaming is to be expected when what is essentially a strong detergent is added to moving water however the degree of bubble formation differs between surfactant products.

Beneficial trace elements

One area of interest to hydroponic growers has always been the use of 'beneficial' mineral elements which are those outside the range of the essential macro and micro nutrients required by most of the plants we grow. While science has identified a total of 17 essential elements (N, P, K, Ca, Mg, S, Cl, Fe, Mn, Zn, Cu, B, Mo, Ni, O, C, H) required by plants for growth, plant matter has been found to contain over 60 elements as diverse as titanium, gold, mercury, arsenic, uranium, sodium and many others. Since plants evolved in soil, they developed the ability to make use of a number of substances and elements, which while not essential for plant growth, have been shown to enhance growth, development and other functions.

Selenium

While selenium (Se) enrichment of food crops for human health benefits has been an area of recent study, selenium may also have a beneficial role in plant growth and development. Plant tissue contains less than 1ppm of Se in most species however selenium is chemically similar to sulphur, a plant macro element, and appears to be metabolised via the same mechanisms. Trace amounts of Se have been found to stimulate growth in a variety of plant species including ryegrass, lettuce and potato and to also provide the plants with more resistance to ultraviolet radiation. There is also evidence that boosting Se levels in hydroponically grown plants can help protect from biotic stress such as fungal diseases.

Cobalt

Cobalt (Co) concentrations in plants are typically in the range 0.1-10ppm on a dry weight basis and cobalt is often found in low levels in natural water sources (0.04ppm). At low levels, cobalt can have a number of beneficial effects, particularly in leguminous plants such as peas where application of Cobalt increases growth, nodule number and weight, as well as seed pod yield and quality. Cobalt may also play a role in slowing leaf aging and in disease resistance in some species.

Since cobalt is also essential for human health, addition of this element to nutrient solutions can enhance the nutritional quality of hydroponic food.

Titanium

Titanium (Ti) is another element whose role in plant development and metabolism has been studied for over 90 years. While plant tissue is generally low in Ti content, being 0.1-10ppm on average, titanium is present in soil in relatively high concentrations. Studies have found that the chlorophyll content of hydroponic tomato plants increased when titanium was added. When maize was provided with titanium in solution the yield increased, and the concentration of sugars in the grain also rose.

Iodine

Another interesting potentially beneficial element is iodine (I). Iodine has been found to stimulate the synthesis of cellulose and the lignification of stem tissue that helps the mechanical strengthening of the plant. Iodine has been found to increase the concentration of ascorbic acid in plants and the amount of total free amino acids in crops grown in solution culture. Iodine also seems to increase salt tolerance in plants by facilitating a lower chlorine uptake.

Silicon

Silicon (Si) is a very common element and comprises more than 25% of the earth's crust. Si is mostly available to plants as monosilicic acid, $Si(OH)_4$, which is taken up from the soil water. In fact, the concentration of silicon in soil is equal to that of many macronutrients such as potassium and calcium and well in excess of phosphate levels. Once inside the plant silicon is deposited as amorphous silica throughout the plant mainly in cell walls. After silicon has been incorporated into plant tissue it cannot be redistributed through the plant so it needs to be in constant supply if the entire plant is to contain a useful amount.

The role of silicon in plants is multifunctional. It contributes to strength and thickness of cell walls which helps to keep plants upright and to position their leaves for good light interception. It plays a role in resistance to attacks by fungi and insects and provides greater tolerance to plant 'stressors' such as high salinity or heavy metal toxicity, drought, UV radiation from sunlight, and extremes of temperature. Several plants actually require silicon as an essential element including rice, sugar cane and tomatoes, while a large number of other species have shown growth benefits including increased absorption and translocation of several macro and micro nutrients.

The use of soluble and slow release forms of silicon as a hydroponic additive is not new. Many cucumber and rose growers are well aware of the benefits of adding silica to the nutrient solution, whether it is in organic or non organic form. Silica in cucumbers, for example, reduces the incidence and severity of powdery mildew and other fungi. Enrichment of the nutrient solution with silicon in hydroponic strawberry crops resulted in a greater number of fruit produced compared to control plants which received no additional silicon. However, silicon in solution should not be considered to be a trace element. Levels as high as 140ppm have been shown to have the most significant effects since silica is naturally found in many plant tissues at up to 10% or higher (dry weight).

Beneficial Trace Elements as Hydroponic Additives

Many water sources, particularly well water, already contain a range of the additional elements found in plant tissue however the levels and types of elements vary depending on the location and soil type. Some beneficial elements also find their way into hydroponic nutrient solutions from dust or tiny amounts of soil contamination and from growing media but growers can intentionally boost these levels by supplementing their nutrient solution. In the early days of hydroponics some growers added small volumes of soil extract or sea water to their nutrient solution to provide a diverse range of micro elements, however since seawater contains large amounts of sodium chloride issues often arose with salt accumulation. There are now far more advanced ways of adding the beneficial elements we want, and excluding those we do not want.

Some of the more widely known beneficial elements such as silica have been available to hydroponic growers for many years and have even been incorporated into nutrient products or developed as an additive. More recently, certain beneficial elements such as selenium and chromium have also been included as additives in some nutrient products. While it's not practical for a hydroponic grower to be able to obtain and weigh out the extremely tiny quantities of the pure salts of these elements, large scale manufacturers of nutrient formulations and hydroponic additives can do this with a high degree of accuracy and ensure growers are using the correct levels of these elements. As a simpler approach, there are other hydroponic additives which contain the minute amounts of many beneficial elements, and most of these are organic or mineral based. Seaweed concentrates, for example, contain a large number of the potentially beneficial elements, as can concentrated vermicast (worm casting) extract, organic nutrients, mineral clay supplements, and a number of other products developed for the hydroponic market.

Bio-stimulants as Hydroponic Additives

A plant bio-stimulant is defined as "*an organic material, that, when applied in small quantities, enhances plant growth and development such that the response cannot be attributed to application of traditional plant nutrients*."

Plant bio-stimulants are a category separate from the synthetic plant growth regulators, although there can be some overlap with certain compounds. Generally, synthetic plant growth regulators are those such as auxins, gibberellins, cytokinins and ethylene which have well known uses in horticulture such as for root formation, fruit set, fruit ripening and others. Bio-stimulants may have similar modes of action, however many have numerous other roles involved in disease resistance, chelation of mineral ions, stress resistance, metabolic enhancement, promotion of microbial populations and regulation of certain physiological and biochemical processes in plants.