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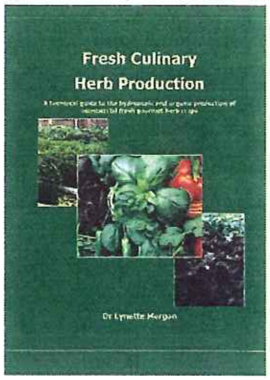
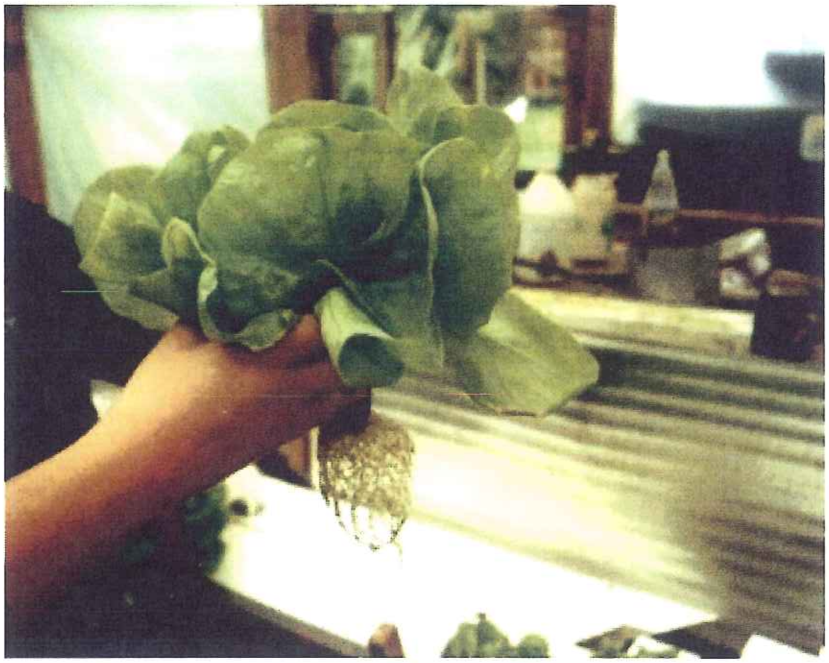


Effect of Spray'N'Grow Foliar MicroNutrient Complex on the Growth, Yield, and Quality of a Hydroponic Butterhead Lettuce Crop



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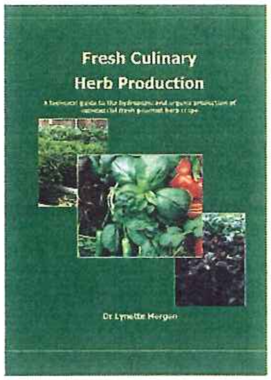

Effect of Spray'N'Grow Foliar MicroNutrient Complex on the Growth, Yield, and Quality of a Hydroponic Butterhead Lettuce Crop

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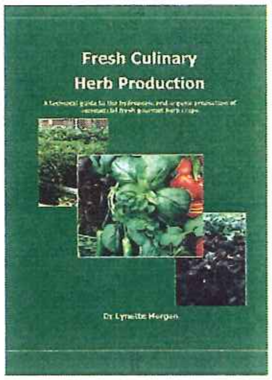
CONTENTS



INTRODUCTION

INTRODUCTION

The principal objective of this research was to determine the effect of Spray-N-Grow micro nutrient complex on the growth, yield, shelf life quality and root weight of a hydroponically grown (NFT) Butterhead Lettuce crop produced under standard greenhouse conditions.

Hydroponic lettuce is a gourmet vegetable grown often sold with the root system intact or processed into salad mixes. Since hydroponic lettuces are smaller and harvested earlier than standard, outdoor crisphead lettuce the shelf life is thus often shorter and more care needs to be taken during handling. The production costs and overheads of hydroponic lettuce production are higher than standard outdoor production - therefore commercial hydroponic growers of crops such as gourmet lettuce and other salad greens need to maximise crop yields using the most cost effective products and proven production techniques. Any cultivation practice which can improve the marketable yield or time to harvest of hydroponic lettuce and other gourmet speciality crops is a valuable tool for a commercial grower.

The results of this trial carried out in New Zealand, with the Spray-N-Grow foliar fertiliser product are outlined in this report. The findings are divided into the variables under observation.

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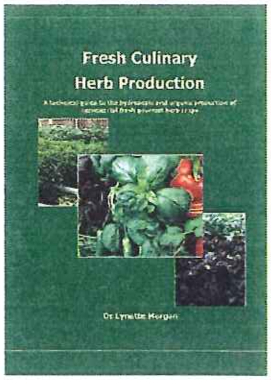

Fresh Culinary Herb Production

Dr Lynette Morgan

BACKGROUND INFORMATION

1.0 BACKGROUND INFORMATION

It is well known that hydroponic systems allow greater control of plant nutrition and can therefore result in improved yields and fruit quality. In hydroponics, the conductivity, formulation, pH and temperature of the nutrient solution all influence yields and produce quality greatly as does the genetic background of the plant and the growing environment.

Nowadays, the use of hydroponic technology to produce a range of `gourmet' fresh vegetable crops is being utilised more and more as consumers come to realise that quality and shelf life are more important than price for many of the vegetable luxury items. Hydroponic Lettuce are one such crop which is recognised as a higher value vegetable with a short shelf life. Therefore any production method with can increase the weight and overall yield of a hydroponic lettuce or salad green crops is well worth investigation. The objective of this trial was to determine the effect of Spray-N-Grow foliar fertiliser product applied weekly on the growth, development, head weight and shelf life of a hydroponically grown NFT, lettuce crop.

1.1 Foliar Fertilisation

The most widely applied method of plant fertilisation is through the root system either via the soil or inorganic media substrates such as those used in hydroponic production. In systems such as NFT (Nutrient film technique) nutrients are supplied dissolved in water with no requirement for a soil media around the roots. While plant root systems are in the most part efficient at absorbing mineral nutrients, certain conditions can prevent optimal uptake rates of some of the elements plants require. Foliar feeding, provides nutrients through the foliage of the plant which has the ability to absorb and translocate certain minerals within plant tissues.

1.2 Benefits of foliar fertilisation

In soil and soil-less systems such as hydroponics, many nutrient interactions can occur within the root zone which makes it difficult for the plant to absorb certain minerals. Soils and even hydroponic systems can become deficient in nutrients - either because of nutrient depletion, antagonism between certain elements, naturally low levels, inadequate fertilisation or due to elements becoming `bound' and therefore unavailable for plant uptake. Imbalances in the combination of nutrients, pH levels which are too high or low for maximum plant uptake, and poor physical properties of the media surrounding the root zone, including oxygen starvation are more common in both soil and soil less systems than many growers realise. Furthermore elements such as iron, an essential trace element, are not only prone to become unavailable for plant use at moderate to high pH levels, their uptake by the plant is also severely limited under certain environmental conditions such as cool temperatures. Iron chlorosis in many crops which are stressed by low temperatures can be a common problem where root uptake is the only source of iron for the plant.

Any situation which damages the root system or restricts its growth, development or physical process such as respiration affects the uptake of minerals. Plant pathogens such as *fusarium pythium* and *phytophthora* can not only rapidly destroy a crop, but low, less damaging levels can restrict function of the root zone to the point where mineral uptake is affected. While the crop may not show signs of severe infection, mineral and water uptake can be restricted to the point where crop yields and quality are affected. Other plant stress conditions such as anaerobic conditions in the root zone where oxygen is limiting, can limit nutrient uptake, with trace elements such as iron often affected to the greatest degree. Any other condition which stresses the plant - temperature stress, high or excessively low humidity levels, lack of light, high radiation levels, high plant densities, presence of pests or disease, will affect the efficiency of the root system in taking up mineral elements. Many of these conditions are common and occur in many commercial production situations without the grower realising that plant growth and mineral uptake is being limited in some way. It is under these types of very common situations that foliar feeding has its greatest advantage. Since plant stress is dependent on a number of factors - many are environmental, which growers have limited control over, foliar fertilisation provides an `insurance policy' against yield and quality loss from limitations in root mineral absorption and transportation.

1.3 The process of foliar fertilisation

As the third organ of higher plants after the shoot and the root, the leaf is essentially used for photosynthesis and respiration. The leaf blade is flat in shape for this purpose. Most leaves have stomata either only on the underside or on both sides of the leaf which enable gas to be exchanged for photosynthesis and respiration as well as releasing water vapour in stomatal transpiration. The leaf with its epidermis can also function as an organ that absorbs and excretes water and substances which may be dissolved in it.

Aqueous solutions are absorbed or excreted not throughout the entire leaf cuticle, but through punctiform areas, the location of which coincides with the position of the ectoteichodes that project radially into the wall. If these structures serve to excrete aqueous solutions from the leaf, then they will also carry out the reverse process i.e absorption into the leaf. This has also been demonstrated with the use of radio labelled materials. Since foliar absorption is limited because of the relative barrier of the cuticle it is not possible to solely feed plants via the leaves. For this reason the most effective use of foliar fertilisation is as a rapid and effective method of supplying the micro nutrients. It can, however also be used to satisfy acute needs with lower concentrations of macronutrients.

1.4 History of foliar fertilisation

As early as 1877 Bohm reported that dissolved mineral salts such as calcium are absorbed via leaf surfaces and used in plant metabolism. In the early 1900's, many researchers provided scientific proof that leaves absorb substances. In 1916 in Hawaii, Johnson sprayed his pineapple crop, which had become chlorotic because of iron deficiency, with a solution of iron sulphate and the plants became green again for a few weeks, this achievement had repercussions in that practical farmers in the US in the 1920's increasingly began to use foliar application of micro elements.

1.5 Application of foliar fertilisers

The addition of a wetting agent or surfactant is vital to the application of foliar fertilisers. Wetting agents are necessary to ensure the adherence of droplets on difficult to wet leaves as well as assisting with the absorption of the fertiliser solution into the plant tissue.

1.6 Timing of foliar nutrient application

One very important criterion of the effectiveness of nutrient sprays is the rate at which the foliar applied nutrients are absorbed by the leaves and translocated within the plant. The uptake of nutrients is further affected by a number of interacting factors of which only part are known at the current time - these are shown in Table 1.1.

Table 1.1 Influences determining the efficacy of foliar nutrient sprays

PLANT	**ENVIRONMENT**	**SPRAY SOLUTION**
Curricular wax	Temperature	Concentration
Epicuticular wax	Light	Application rate
Age of the leaf	Photo period	Application technique
Stomata	Wind	Wetting agent
Guard cells	Humidity	pH
Trichomes, leaf hairs	Drought	Polarity
Adaxial leaf side	Time of day	Hygroscopicity
Abaxial leaf side	Osmotic potential of root	Sticking ability
Leaf Turgor	Nutrient stress	Sugars
Surface moisture (dew etc)		Nutrient ratio
Cation exchange capacity		Carriers, penetrates
Nutritional status of the plant		Humectants
Cultivar		
Growth stage		

If in certain crops and for certain nutrients, foliar application at an early growth stage is recommended, it is necessary to reach a compromise between early application and allowing the crop to attain a leaf area large enough for the absorption of large amounts of nutrients.

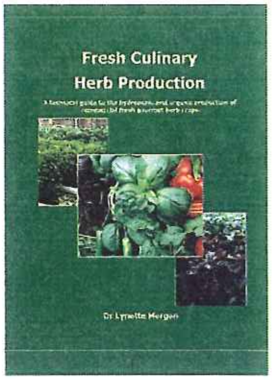
Most crops have certain growth stages needing a particular supply of all or of certain nutrients to reach optimum yields. Plant demand is generally at its maximum during the period of exponential growth. During such critical stages, leaves show a particularly high efficacy for absorbing nutrients. Furthermore, at any stage during growth and development, there are times when nutrient uptake by the root system is impeded to such an extent that plant tissues may not receive an adequate supply of nutrients. Examples of this are during drought or high salinity conditions. During times of limited nutrient uptake due to water stress or other conditions, foliar fertilisation during these critical growth stages, is a means by which full yield can still be ensured.

If a period during which the plants have difficulty in absorbing nutrients via the root system should coincide with a period when there is a particularly vigorous demand for nutrients, the result will be a significant loss in yield potential, without the grower seeing any visible signs of deficiency. Under such conditions foliar fertilisation can give particularly impressive results.

1.7 The role of foliar fertilisation in hydroponic crops

While hydroponic crops may appear to be supplied with optimal nutrition via a well balanced and formulated nutrient, they still benefit from the application of foliar fertilisers. Previous researchers have found that hydroponic crops such as capsicum, treated with a micro nutrient foliar applied solution had an increase in fruit yield over control plants and also an increase in the compound capsaicin in the fruit tissue. Hydroponically cultivated potato plants also showed similar results. Potato plants given foliar fertilisation treatments with a micro nutrient solution not only had a greater tuber harvest, but also higher dry matter of the whole plants. Experimental results with hydroponically grown greenhouse tomato crops have proven that foliar application of certain trace elements can not only increase yields but also the quality of the fruit in terms of brix (sugar levels), flavour and shelf life. Yields and pod numbers in hydroponically grown Snow Peas have also proven to be increased with the use of foliar fertiliser applications.

These results would also be expected on a number of hydroponic crops with similar nutrient requirements and thus the process of foliar fertilisation is a cultivation technique that must be considered in any commercial production system.



MATERIALS & METHODS

2.0 MATERIALS AND METHODS

2.1 Objective

To determine the effect of applications of Spray-N-Grow micro nutrient foliar fertiliser complex applied on a weekly basis to an NFT (nutrient film technique) hydroponic Butterhead lettuce crop as compared to a control, untreated crop. To determine the effects of these treatments on such factors as plant growth rate, head weight at harvest, total yield, root dry weight, leaf mineral levels and shelf life.

2.2 Treatments

1. Weekly foliar application of Spray-N-Grow (SNG) micro nutrient foliar complex at a rate of 10ml per litre of water sprayed to run off.

2. Control - no treatment applied.

2.3 Experimental Design

A complete randomised block design was used for this trial. Plants were shielded with plastic covers during application of the SNG treatment until all foliage was dry.

2.4 The Crop Production System

The trial was conducted in a naturally ventilated greenhouse during the late Summer period in Tokomaru, New Zealand. Seedlings of the commercial Green Butterhead lettuce variety `Erika' were sown into plastic propagation tubes with a sterilised perlite media on 27th December 2002. After germination and the production of the first two true leaves, seedlings were grown on for 2 weeks before being transferred into the NFT (nutrient film technique) system in early January 2002. A density of 12 plants per square meter was used, with a total of 20 plants per replication (3) of each treatment. When the seedlings had developed a sufficient leaf area the first SNG treatment application as given on 16 January 2002 and every week thereafter until crop completion

A standard hydroponic nutrient solution (NFT Lettuce formula given in Appendix one) was applied at an EC of 1.2 and a pH of 5.8 for the life of the crop. EC and pH were adjusted daily.

Plants were grown under standard greenhouse conditions in a naturally ventilated greenhouse. Temperatures during this period ranged from a daily minimum of 16 °C (night minimum of 12 °C) to a daily maximum of 28 °C (night maximum of 22 °C).

All plants receiving the SNG treatment were sprayed in the early morning when stomata are expected to be open for nutrient absorption. Control plants were shielded with plastic sheeting until foliar treatment leaves were dry.

2.5 Preparation of the Spray-N-Grow Foliar solution

Distilled water used as a carrier for the SNG product was warmed to 100F (38° C). The pH of this water was increased to 7.1 using a dilute solution of sodium bicarbonate. 10ml of SNG per litre along with ½ teaspoon of cocowet surfactant was added to the warmed water in a 4 litre sprayer and left for 20 minutes. After this time, the solution was sprayed onto the treatment plants with a small hand held pressure sprayer to the point of run off. Care was taken to apply the solution to as much of the upper and lower leaf surfaces as possible for maximum efficiency.

2.6 Crop Measurements

The size and development of all plants during the early treatment phase was noted. After the final harvest, all lettuce heads were removed, the system switched off and drained. Root systems were collected, labelled and left to air dry these were then weighed for each replication and treatment block.

2.6.1 Harvesting

Harvesting took place on 16 February 2002, when the crop was terminated. This was the stage when more than 50% of the lettuce heads were determined to be of a marketable size. Each head was weighed, and assessed for marketability.

2.6.2 Shelf Life Assessment

Shelf life is an important variable in the post harvest handling chain and is of concern to all who grow, process, market, transport and consume the final fresh product. The shelf life of hydroponic lettuce can vary considerably depending on a number of factors including the percentage dry matter of the foliage (i.e. how much water is present to be lost before wilting occurs), presence of any disease/pathological or physiological problems, head weight and formation, the percentage of certain minerals contained within the foliage (calcium in particular), general plant health and the conditions the crop were grown under.

Shelf life assessment of this crop was carried out by selecting 15 lettuce heads (5 from each replication) from the SNG and control treatments, of a similar size and exact same degree of maturity at on the date of harvest. Each head was weighed at the time of harvest and again at 2 day intervals until it was determined to be of unacceptable quality. A final weight was taken to determine the percentage of water lost during the shelf life period and the reason for loss of shelf life recorded. This was usually due to wilting or loss of chlorophyll resulting in a yellowing of the tissue.

2.6.3 Root Dry Weight

The mass or dry weight of the root system of a crop often gives and indication of the health of the plants and plant stress factors usually result in a smaller root mass/thinner individual roots and the presence of pathogen damage. Since fresh root systems contain a large amounts of water in their capillary system, dry weight is the best method of determining differences in the root system. Root systems of each plant were detached from the head at harvest, any remaining media from the propagation tube removed and the root system was air dried for a period of three weeks. After this time, all the moisture had been removed from the root system and dry weights were recorded for each treatment replication.

2.6.4 Foliar Mineral Levels

Leaf tissue samples were selected for mineral analysis at the time of harvest. Leaf tissue was analysed by Hill Laboratories, Hamilton, New Zealand to determine levels of Nitrogen, Phosphorus, Potassium, Sulphur, Calcium, Magnesium, Sodium, Iron, Manganese, Zinc, Copper and Boron. These levels were compared between the SNG treated and untreated (control) plants.

2.7 Statistical analysis

All data was analysed by comparison of standard errors and at the 10% probability level using the Simstat programme for statistical analysis.

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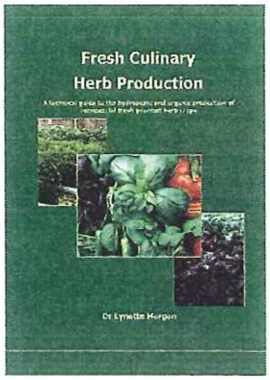


RESULTS & DISCUSSION

3.0 RESULTS AND DISCUSSION

3.1 Treatment effects on crop growth and development

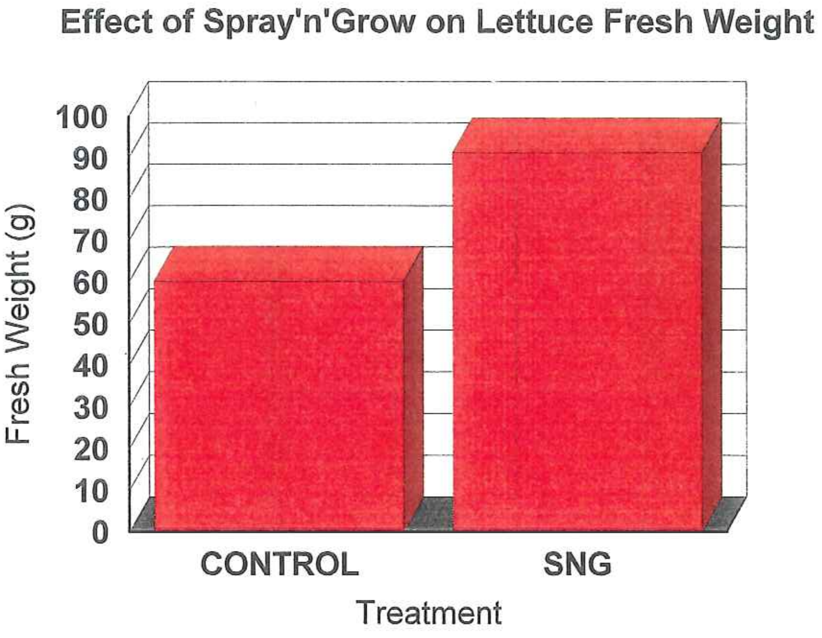
While initial seedling growth was similar in both treatments, the SNG treatment plants were larger with a greater leaf area within 2.5 weeks of the first treatment - hence there was a significant increase in head weight at the time of harvest. Root outgrowth and root matt development appeared to be visibly more advanced inside the hydroponic channels in the SNG treatment.

3.2 SNG Treatment effects on head weight at harvest (yield)

At the time of harvest on 16 February 2002, significantly more SNG treated plants were of a marketable weight as compared to the control treatment. This was a result of earlier crop establishment in the NFT system, faster rate of foliage growth and head development in the SNG foliar treatments This indicates an increase in `early harvest' yield from the treated plants.

At the time of harvest, the SNG treated plots had an average head weight of 91.25 g per plant with a 95% marketability (s.e = 13.65, 90% CI = 68.38 - 114.12). The control plots had an average head weight of 60.16 grams per plant, with a 65% marketability (s.e = 3.25, 90% CI = 54.7 - 65.6). Unmarketable heads were those which were too small to be marketed as a single hydroponic butterhead lettuce.

Figure 1. Effect of SNG treatment on lettuce head weight.



3.3 SNG Effects on head shelf life

Shelf life assessment was carried out on selected heads from the final harvest. The results from this shelf life trial showed no significant difference in storage times and post harvest moisture loss between the treatments (SNG and control). However after the 10 day storage period, the SNG treated heads were had less yellowing and wilting on the outer wrapper leaves than the control plants. On average, all heads had a shelf life of 10 days under refrigeration at 2 C stored in polythene bags. Loss of shelf life was the result of slight wilting and loss of crispness due to water loss and a loss in green coloration resulting in yellowing of the foliage. At the final assessment after 10 days in refrigerated storage, the following was noted for each treatment.

Control: All heads had yellowing of the outer leaves and wilting of the outer wrapper leaves. There was some evidence of \`tipburn' on many heads.

SNG treated heads: Some slight yellowing of the wrapper leaves. Less wilting and moisture loss than the control heads. No significant difference in shelf life, however there were slight differences in quality at the end of the shelf life period with the SNG treated heads being of better marketable quality at the end of the 10 day storage period.

The SNG treated heads were of a heavier weight and larger size than the control heads at the time of shelf life assessment as this may account for the better condition of these after the 10 days storage period under refrigeration.

3.4 SNG treatment effects on root dry weight

There was a significant increase in root dry weight per plot from the SNG treatment plants (Figure 2). Control root system plots averaged 110g dry weight per plot. SNG treatment plots averaged 181.3 g per plot. Since the SNG treated plants also had a significantly higher head weight, root dry weights were also expected to be greater from this treatment.

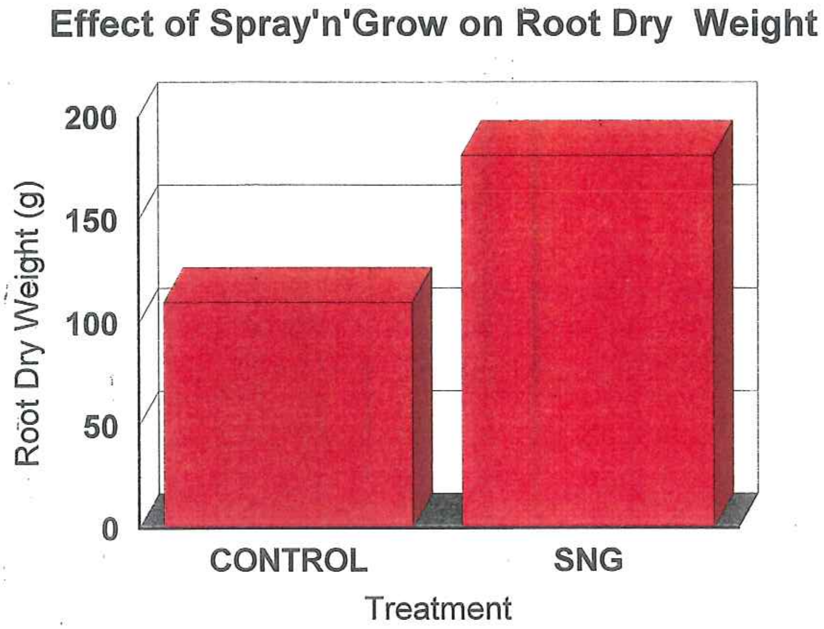


Figure 2. Effect of SNG foliar fertiliser on lettuce root dry weight values

3.5 SNG Treatment effects on foliar mineral levels

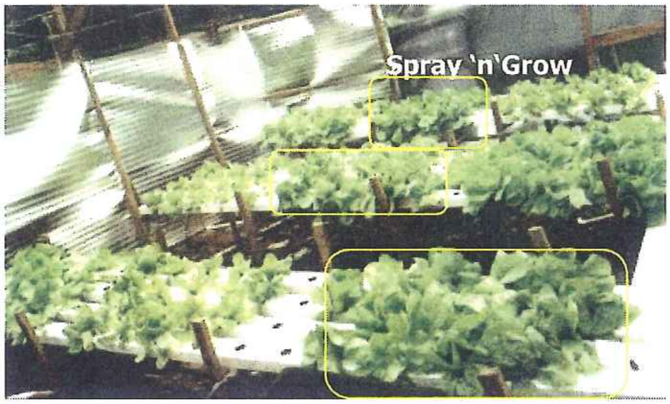
The foliar mineral level values for the SNG treatment and control plants at the time of harvest is shown in Table 2.

Table 2. Effect of SNG treatment on leaf foliar mineral levels
(Analysis by R J Hill Laboratories Ltd, Hamilton, New Zealand)

Element	Unit of measure	SNG	Control
Nitrogen (N)	*Percent*	*5.7*	*5.4*
Phosphorus (P)	*Percent*	*0.73*	*0.66*
Potassium (K)	*Percent*	*7.4*	*10.3*
Sulphur (S)	*Percent*	*0.27*	*0.24*
Calcium (Ca)	*Percent*	*1.64*	*2.14*
Magnesium (Mg)	*Percent*	*0.42*	*0.49*
Sodium (Na)	*Percent*	*0.12*	*0.12*
Iron	*ug/g*	*295*	*224*
Manganese	*ug/g*	*251*	*375*
Zinc	*ug/g*	*288*	*250*
Copper	*ug/g*	*9*	*7*
Boron	*ug/g*	*15*	*17*

Since the SNG foliar fertiliser contains iron and zinc, this may account for the increased levels of these in the SNG treatment sample, since some may still be present on the leaf tissue and on the surface of the leaves. All other element values are at acceptable levels, although potassium levels are high in both treatments.

Spray'n'Grow Treatment Blocks after 3 x weekly applications of S'n'G



Spray'n'Grow Treatment Blocks after 4 x weekly applications of S'n'G

Spray'n'Grow treated lettuce head (right)

Spray'n'Grow treated Lettuce at harvest

Lettuce head samples from three different treatments
1: SNG
2: SNG/BPF
3: Control, after 10 days storage at 2°C

Spray'n'Grow treated head had less wilting and tissue discolouration after 10 days storage

4.0 Conclusions and summary

Treatment with the SNG foliar micro nutrient complexes has previously been proven the boost the plants foliar levels of zinc and iron (two important trace elements) in hydroponic tomato crops. Zinc is a co-factor in the production of chlorophyll and is also involved in the formation of the plant hormone auxin. Auxin is implicated in the transport of photosynthates from leaves to developing `sinks' such as fruit and roots. Iron is an integral part of proteins involved in electron transfer across membranes in chloroplasts, utilised in the photosynthetic process. Optimum levels of available iron enhance photosynthesis, by allowing the unimpeded flow of electrons, and hence maximise sugar formation in the leaves. In this way, it appears that the SNG micro nutrient complex affects many plant processes which in turn influence growth rates and yields.

Furthermore, even in hydroponic systems, the uptake of elements such as iron can be limited by factors such as pH level, interactions with other ions, conditions within the root zone and low temperature. This can result in lower than optimal levels of certain plant nutrients without the crop showing any visible signs of deficiency. It appears that boosting foliar mineral levels with the use of a micro nutrient complex not only rectifies any deficiency in root uptake, but also has a synergistic effect on many plant processes.

The SNG treatment had the effect of advancing crop establishment into the NFT system, early crop growth and head development - this could be an effect of improved plant nutrition, assisting the plants to absorb minerals in an environment where root uptake might be limiting. However there may be other as yet unexplained reasons why the SNG complex benefits plant physiological processes and assists growth and head formation. The increase in root dry weight in the SNG foliar treatment over the control plants indicates the greater nutritional status of the treated plants.

Foliar fertilisation with the SNG micro nutrient complex can result in not only more rapid plant establishment and earlier growth with greater final head weight (yield) and improved shelf life - an important consideration for any commercial hydroponic producer.

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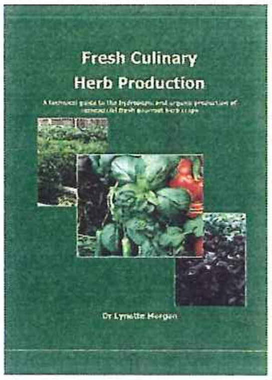

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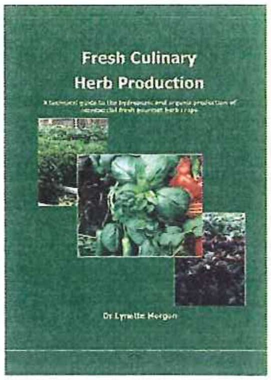

APPENDIX ONE
Hydroponic Lettuce Nutrient Formula

APPENDIX ONE

NFT LETTUCE NUTRIENT FORMULA

Standard hydroponic nutrient formula for high quality, low mineral water sources.

This nutrient formula contains the following element contents:

Macro Nutrients in ppm	**Micro Nutrients in ppm**
Nitrogen (N) 139 ppm	Iron (Fe) 3.00 ppm
Potassium (K) 25 ppm	Zinc (Zn) 0.25 ppm
Phosphorus (P) 98 ppm	Boron (B) 0.70ppm
Magnesium (Mg) 25 ppm	Copper (Cu) 0.07ppm
Calcium (Ca) 150 ppm	Molybdate (Mo) 0.05ppm
Sulphur (S) 33 ppm	Manganese (Mn) 1.97ppm

Nutrient salts by Weight

Stock soluton volume 100 litres, dilution rate 1:100 to give an EC of 1.2, pH of 5.8, TDS of 840.

Part A

Calcium Nitrate	7505.4 g
Potassium Nitrate	875.40 g
Iron EDTA	500g

Part B

Potassium Nitrate	875.4 g
MonoPotassium phosphate	1191.3 g
Magnesium sulphate	2552.8 g
Manganese sulphate	80 g
Zinc Sulphate	11 g
Boric acid	39 g
Copper sulphate	3.02 g
Ammonium molybdate	1.022 g

DISCLAIMER

SUNTEC International Hydroponic Consultants take no responsibility for the misuse or misinterpretation of the data, results or conclusions stated in this report.

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