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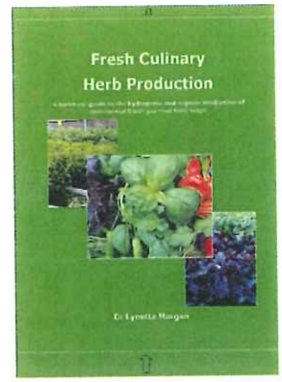

Effect of Spray-N-Grow Foliar Micronutrient Complex alone and in Combination with Bill's Perfect Fertiliser on the Growth, Yield and Quality of Hydroponic Strawberry Crops.

Dr Lynette Morgan PhD & Simon Lennard M.Hort.Sc

SUNTEC International Hydroponic Consultants

New Zealand

2002 - 2003

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SNG'

Dr Lynette Morgan PhD and Simon Lennard M.Hort.Sc

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CONTENTS

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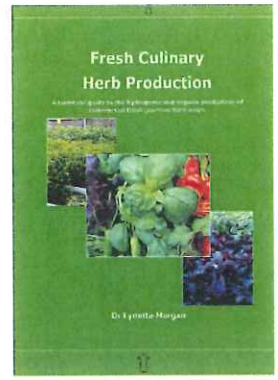

INTRODUCTION

INTRODUCTION

The principal objective of this research was to determine the effect of Spray-N-Grow micro nutrient complex alone and alternated with Bill's Perfect Fertiliser concentrate on the growth, yield and quality of hydroponically grown strawberry crops produced under heated and unheated greenhouse conditions.

Strawberries are a widely grown field crop producing fruit in the late Spring to early Fall season. Hydroponic strawberry production has in the past, focused on the out of season, winter and early spring fruit markets when premium prices can be obtained for high quality fruit. However, with the upcoming ban on the use of soil sterilisation chemicals, which soil based strawberry producers are heavily reliant on to maintain yields and production, hydroponic production is being turned to as an alternative method for year round berry production. Commercial hydroponic strawberry crops are becoming more widespread, as well as the plant being a popular fruiting crop for small, hobbyist and backyard growers. Strawberry plants have certain requirements for hydroponic production, including specific root zone conditions and nutrition when fruiting. Plant establishment from field grown runners can be slow as new roots must be developed from the plants' crown and mineral uptake by the plant is significantly slowed under low temperature and light conditions. Hydroponic strawberry fruit, particularly that produced out of season when light levels are low, often suffers from a lack of sugars and flavour quality. Any cultivation practice which can improve the early growth rate, establishment and long term yields of high quality fruit is a valuable tool for any commercial strawberry grower.

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

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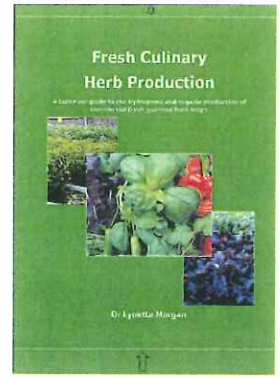

BACKGROUND INFORMATION

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.

The objective of this trial was to determine the effect of Spray-N-Grow foliar fertiliser alone and a combination of Spray-N-Grow alternated with Bill's Perfect Fertiliser (as a foliar spray) applied weekly on the growth, development, yields and fruit quality of a hydroponically grown strawberry 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 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		

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 is 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

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 Foliar Fertilisation of fruit and berry crops

Foliar fertilisation treatments with various nutrient combinations has been examined on a number of different fruiting crops including strawberries, raspberries and many tree grown fruit. In a study carried out on field grown strawberry plants in Florida, it was found that the greatest response to foliar fertilisation (N, P, K) occurred when there was marginal rates of applied soil fertiliser, and that the foliar fertilisation treatment did generally increase fruit yields under these conditions (Albregts and Howard, 1986).

Similar results have been found in other berry crops, including raspberries where researchers found that foliar applied N and K were absorbed rapidly into the leaf and transported throughout the plant. In raspberries it was observed that the lower leaf surface exhibited a faster rate of absorption than the upper leaf surface. This experiment concluded that significant uptake of foliar applied N and K occurs in raspberry plants, however the amount delivered through a single foliar application is small, and regular ongoing applications are required throughout the growing season for maximum effect (Reickenberg and Pritts, 1996).

Other studies have found that foliar fertilisation applications are beneficial to a wide range of fruiting crops including `French prune' in which sprays of potassium nitrate applied several times during the growing season have been proven to correct incipient K deficiencies and obtain higher dry yields (Southwick and Wis, 1996). Similar results have been found on Pecan trees where foliar applications of N and K improved the nutritional status of the trees and prevented the common problem of reduced yield and nut quality due to potassium deficiencies. Foliar application of iron based nutrients is often used for the treatment and prevention of iron chlorosis (often `lime induced' chlorosis) on citrus crops where the treatment is highly effective in treating this disorder. Yield from citrus trees grown on limed soils can be low due to the negative effect on root based iron uptake under these conditions. Foliar applications of iron is the most effective way to correct lime induced chlorosis since applications of inorganic iron compounds to calcareous soils are useless. The results presented from one study stated that foliar sprays of inorganic iron compounds, when coupled with low-surface-tension surfactants correct iron chlorosis and restored the photosynthetic activity of chlorotic leaves, as well as peroxidase activity and chlorophyll contents. The results also suggest that foliar applications are more effective than a soil application of 15 kg. ha^{-1} of sequestrene Fe 138 chelate (Horesh and Levy, 1981).

Peach trees, like many fruiting crops, have also been found to respond to foliar applications of trace elements such as iron and zinc. Under rapid growth of new shoots in warm climates, zinc and iron deficiencies have been noted in peach crops and foliar levels of these trace minerals have been successfully boosted with foliar applications of zinc and iron (Grewal et al, 1991).

1.8 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. Other researchers have found that foliar applied salts such as Urea, NH_4NO_3, $Ca(NO_3)_2$, $NaNO_3$, K_2SO_4, $MgSO_4$ significantly increased the total, marketable and first number fruit yield on greenhouse grown tomato crops (Komosa, 1984).

Recently, trials carried out on greenhouse grown hydroponic tomato, snow pea and lettuce crops have proven that foliar fertilisation can in fact significantly increase yield in many cases and also improve fruit quality in terms of Brix (sugar levels) percentage dry matter and shelf life (Morgan & Lennard 2001, 2002). 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 should be considered in any commercial production system.

1.9 Hydroponic Strawberry production - Background

The United States is the largest producer of strawberries in the world, however in the past, much of this production has been carried out in the field. World-wide, soil grown strawberry production relies heavily on the use of fumigation chemicals to control soil-borne insects, pests, diseases and weeds. Without this fumigation of strawberry soil beds, it's estimated that yields from field grown strawberries would be cut in half. With the approaching ban on the use of methyl bromide as a soil fumigant, and the resulting losses in production, many commercial strawberry growers are seeking alternative production systems and soilless cultivation, or hydroponics is the logical answer.

Under hydroponic production, many growers must obtain `field grown' strawberry runners in Fall and then refrigerate these for the required number of weeks to fulfill the plants' dormancy requirements. The pre-chilled runners must then be established into the hydroponic system to re grow a healthy root system and produce new leaves, flowers and fruit. Establishment of field grown runners, after chilling in a hydroponic system can be a slow process, particularly during winter or early spring when light levels are low and conditions cool. During this time, the plant has very little root tissue capable of nutrient uptake, until the new root systems develop from the base of the plant's crown. Hence early leaf growth is often limited by root uptake of nutrients from the nutrient solution applied soon after planting out. Strawberry nutrition in hydroponics is also often limited by cool solution and/or air temperatures which limit the uptake of iron in particular, with strawberry plants being particularly prone to iron chlorosis in winter or where the root system has been damaged. Strawberry crops grown out of season, under low temperatures are particularly prone to iron deficiencies which results in leaf chlorosis (yellowing) once foliar levels fall below 20 ppm. Yield and the number of fruit per plant and fruit set are adversely affected by iron deficiency which often occurs under cooler conditions when iron uptake is inhibited. Strawberry plants are also prone to a number of root rot pathogens including *phythophthora* (red stele) and many other root and crown rots which can slow plant growth and development and even result in crop losses.

The strawberry root system can be difficult to maintain in healthy condition in many systems, as it has specific requirements for oxygen and will not tolerate any over saturation of the growing media or root zone. Strawberry plants are sensitive to salinity and root zone temperature and many environmental conditions can result in slow growth and low yields. Plant nutrition in strawberries is not as straight forward as other crops, as the root system of these plants is often compromised either during establishment, or at other times during the plants' cropping cycle. Therefore applying a well balanced nutrient solution does not always guarantee optimum nutrient uptake. A well grown strawberry crop can carry a high fruit load for the size and leaf area of the plant, hence attention to plant nutrition is vital to maintain not only yields but also fruit quality.

Strawberry quality, particularly flavour is another important aspect of hydroponic crop production. Often, out of season berries lack sweetness due to lower light and temperature conditions, which in turn also slow nutrient uptake. Strawberry flavour can be improved in most modern cultivars with the use of environmental and nutritional modification. However, there is often a trade off between flavour improvement and yields. In many cases the greater the flavour profile in a strawberry fruit, the lower the fruit weight.

Other fruit quality characteristics which are important for hydroponic strawberry production are the shelf life, firmness (related to the percentage dry matter in the fruit) and ascorbic acid (Vitamin C) content of the fruit which is becoming of concern to fruit and vegetable consumers. Production practices which increase the shelf life, firmness, flavour and ascorbic acid concentration in strawberry fruit are now becoming as important as obtaining maximum yields from strawberry crops. With average hydroponic strawberry yields currently being in the range 300 - 1400 g per plant per season, there exists much room for improvement in growing practices to obtain the maximum amount of top quality fruit using hydroponic methods.

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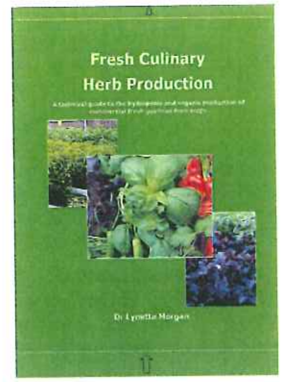


MATERIALS AND METHODS

2.0 MATERIALS AND METHODS

2.1 Objective

To determine the effect of applications of Spray-N-Grow alone and alternating weekly with Bill's Perfect Fertiliser on NFT (nutrient film technique) and media based hydroponic strawberry crops grown under heated and unheated conditions. To determine the treatment effects on such factors as plant growth rate, foliar mineral levels, berry yields, fruit quality including brix, percentage dry matter, flavour, vitamin C (ascorbic acid) content and shelf life. To determine whether the foliar treatments are more beneficial in heated or unheated crops and also in NFT vs media grown plants.

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, plus 1/8 teaspoon of Cocowet sprayed to run off.

2. SNG (rate as above) applied one week, BPF (Rate of 5 ml per litre plus 1/8 teaspoon cocowet) in the next week - alternating weekly.

3. 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 SNG and BPF until all foliage was dry.

2.4 The Crop Production System

These trials were conducted in a naturally ventilated greenhouse from July 2002 to May 2003 (winter, spring, summer and fall periods).
A standard hydroponic nutrient solution (Strawberry formula given in Appendix one) was applied at an EC of 2.0 and a pH of 5.8 for the life of the crop. EC and pH was adjusted daily.
Temperatures during this period ranged from a daily minimum of 4° C (night minimum of 2°) to a daily maximum of 32° C (night maximum of 26° C).

This experiment was divided between three production systems
1. Heated NFT (nutrient film technique) system - with greenhouse heating supplied. in the July - November period to maintain air temperatures above 16° C day and 10° night. System contained approximate 300 plants in 3 replications

2. Unheated NFT system - grown under naturally ventilated greenhouse conditions. System contained approximately 200 plants in 3 replications.

3. Unheated media based (pine bark media in shallow beds) system. System contained approximately 360 plants in 3 replications.

Freshly dug strawberry runners of the commercial variety `Yolo' were purchased from a licensed propagator (Virus and disease free stock) in early May 2002. All runners where washed to remove excess soil and given a chilling treatment of 8 weeks at 2 ° C - this is required to induce flowering after planting in the day neutral variety selected. On 1 July, the pre-chilled runners were prepared for planting by removing larger, older leaves and drenching with a fungicide to prevent disease carry over from the soil grown plants. SNG and SNG/BPF treatment plants were then soaked for 30 minutes in a solution of SNG (10 ml per litre plus 1/8 teaspoon per litre of cocowet). All plants were placed into the heated and unheated hydroponic systems on 3 July, Plants were sprayed with a Trichoderma product (Tricho-flo, Agrim Technologies) and this was also added to the nutrient solutions as additional protection against root disease pathogens such as `Red Stele'. Nutrient EC was initially run at 1.0 for the first 2 weeks during plant establishment and early root growth, then increased to 2.0. pH was maintained at 5.8 - 6.0. Temperatures (late winter) averaged 16 - 24 ° for the heated crop and 2 - 16 ° C for the unheated crop. Heating was discontinued in early summer for the heated crop.

Pollination was carried out by hand on all strawberry crops by gently brushing over the plants during flowering (bees were also naturally present in the greenhouse during the spring and summer seasons). Aphid and caterpillar infestations were controlled in the early stages with the use of Neem based pesticides (applied at least 72 hours before SNG, BPF treatment applications). Bird attack on the ripe fruit inside the greenhouse was initially a concern, but was rectified with the use of bird netting over all plants.

All plants receiving SNG and BPF treatments were sprayed in the morning when stomata are expected to be open for nutrient absorption, apart from days with particularly cold conditions (light frosts) when spraying was not carried out until crop temperature reached at least 7 ° C. Control plants were shielded with plastic sheeting until foliar treatment leaves were dry.

2.5 Preparation of Spray-N-Grow, and BPF Foliar solutions

Distilled water used as a carrier for the SNG and BPF products was warmed to 100 ° F (38° C). The pH of this water was increased to 7.1 using a dilute solution of sodium bicarbonate. 10ml of SNG or 5 ml of BPF along with 1/8 teaspoon of cocowet surfactant was added per litre of warmed water and left for 20 minutes. After this time, the solution was sprayed onto the SNG treatment plants with a small hand held pressure sprayer (4 litre capacity) 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

2.6.1 Growth rate and establishment observations

The size and development of plants and rate of establishment during the early treatment phase was noted as was the timing of initial floral development and fruit set.

2.6.2 Harvesting and yields

The first harvest from the heated NFT system took place in late September 2002. Final harvest dates were in May 2003. Fruit from each treatment plot and replication were weighed from each of the three systems. All fruit were harvested at the pink-red stage of development. Fruit samples from each treatment plot were then either frozen for brix and ascorbic acid assessment, dry weighted or selected for shelf life assessment.

2.6.3 Fruit Brix (sugar) level testing

Samples of 20 fruit from each system and treatment replication, of similar size and same degree of ripeness were selected from each of 7 harvest dates. These fruit were left to ripen to full colour under room temperature conditions and then frozen. After 3 days each sample was defrosted, put through a juicer and the remaining extract filtered through laboratory grade filter paper. The clear extract was then placed on the plate of a refractometer (brix meter) and a reading taken 3 times. Brix levels are an indication of the sugar levels within the fruit and are highly correlated with the `sweetness' variable measured by taste panellists. Fruit with higher Brix readings tend to result in sweeter fruit as can be measured by human tasters. Brix levels in strawberry fruit can vary from 6.0 (low) to up to 10 (very high) and like dry matter percentage, are influenced by factors such as cultivar, season, nutrition, light levels, EC levels and general crop health.

2.6.4 Fruit Percentage Dry matter determination

Samples of 20 fruit of a similar size and same degree of ripeness were selected from each system and treatment replication on each of 2 harvest dates. These fruit were weighed then desiccated on a low heat for 24 hours until no moisture remained. The fruit samples were then re-weighed and percentage dry matter determined. Strawberries are typically 8 - 12% dry matter depending on season, cultivar and growing conditions. It is recognised that a high dry matter results in firmer fruit with a greater shelf life, although overly high dry matter can result in `tough' or `woody' strawberry fruit texture.

2.6.5 Fruit Ascorbic acid (vitamin C) determination

The clear filtrate taken from the fruit prepared for Brix testing was also used for ascorbic acid (vitamin C) determination. 3 x 10 ml samples of clear filtrate were diluted with 10 ml of distilled water for testing. Ascorbic acid levels were determined with a R Q Flex Plus (Merck) using 25 - 450 mg/litre test strips. Results were collected as ppm or mg/litre of ascorbic acid in each sample. Environmental conditions, nutrition, cultivar and other production factors are known to affect the levels of vitamin C in hydroponically grown fruits and vegetables. High ascorbic acid levels are associated with good fruit quality and are desirable to obtain in strawberry fruit.

2.6.6 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 fresh strawberry fruit can vary considerably depending on a number of factors including the percentage dry matter of the fruit (i.e how much water is present to be lost before shrivelling occurs), whether the fruit is affected by any diseases/pathological or physiological problems, the percentage of certain minerals in the fruit (calcium in particular) and the conditions the fruit are grown under. Strawberries are a soft fruit which is prone to rapid softening post harvest and can be severely affected by post harvest rots such as Botrytis. Shelf life of strawberry fruit post harvest at room temperature is typically only a few days, however fruit will store for up to 10 days under refrigeration with the use of plastic wraps to prevent excessive moisture loss.

Shelf life assessment from these trials were carried out by selecting 25 fruit of a similar size and exact same degree of ripeness at each of two harvests. Fruit were stored at room temperature (constant 20 $^{\circ}$ C) and assessed daily for quality deterioration, until each sample was determined to be of unacceptable quality. Fruit typically softened and developed post harvest rots after several days of storage.

2.6.7 Foliar mineral levels

Leaf tissue samples from each treatment were collected for foliar analysis in April 2003. Mature leaves and petioles from a randomly selected sample of plants in each treatment were taken for mineral analysis which was determined by R J Hill Laboratories, Hamilton New Zealand. Leaf tissue was analysed to determine levels of nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, sodium, iron, manganese, zinc, copper, and boron.

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.

SNG/BPF Hydroponic Strawberry Trial 2002

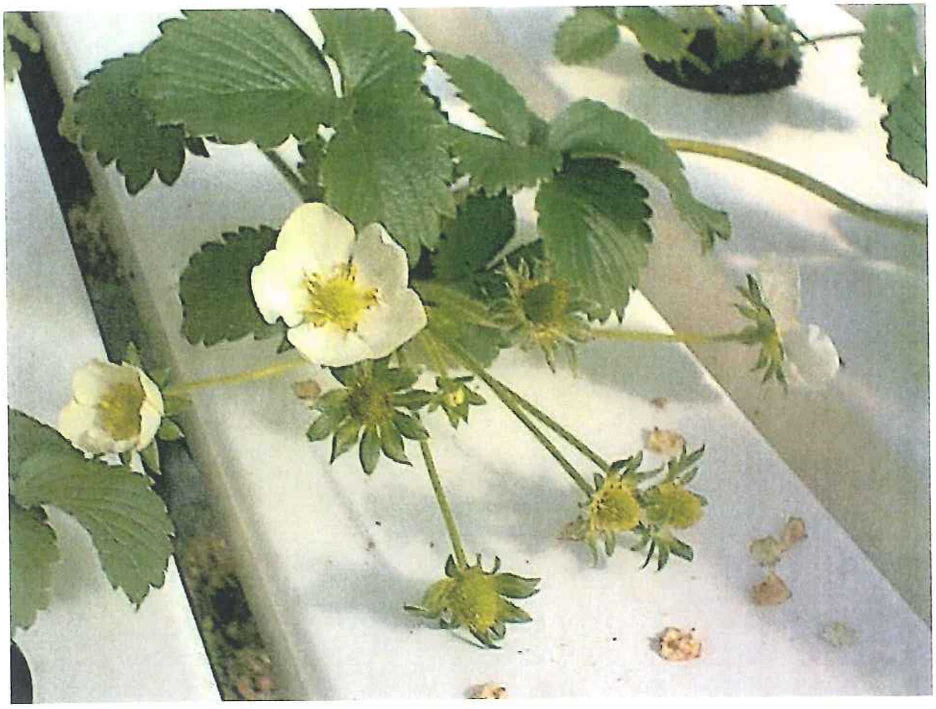
Left. Prechilled strawberry runners at the time of planting into the NF system (3 July 2002)

Left: NFT system 5 weeks later, old foliage has been removed, plants are flowering.

SNG/BPF Hydroponic Strawberry Trial

Media grown crop
20 August 2002
(unheated)

Media grown Strawberry plants showing new foilage developing



SNG Treated hydroponic strawberry plant showing flower truss development and healthy foliage

Part of the SNG/BPF heated NFT crop trial. Mid August 2002

3. Part of the unheated, media based hydroponic strawberry SNG trial in late September

Applying SNG Treatment to Hydroponic Strawberry trial, November 2002.
(Dr Lynette Morgan - SUNTEC International Hydroponic Consultants)

Part of the Heated NFT Strawberry Trial November 2002

Treatment application on NFT strawberry trial

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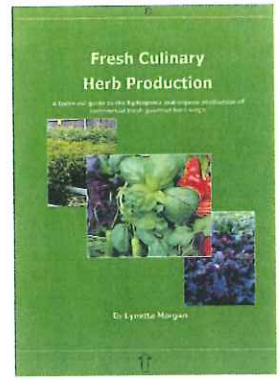


RESULTS AND DISCUSSION

3.0 RESULTS AND DISCUSSION

3.1 Treatment effects on runner establishment and early plant growth and development

Pre chilled strawberry runners were planted into all heated and unheated hydroponic systems in early July 2002. At this stage the plants only had the remains of the old, soil grown root system, and 1 - 3 older leaves, the crowns from which new root and shoot growth emerges were healthy. Typically runners planted out in mid winter are slow to develop due to cool growing conditions, however new root initials were noted on all plants within one week of planting out.

It was noted that during the establishment phase, the SNG and SNG/BPF treated plants developed significantly faster than the control plants. Most notable was the advanced development of the foliage in the first few weeks, with both a greater number of leaves and larger leaf size. The heated crop had growth advanced by 3 weeks over the unheated crops, irrespective of treatment applied. In September, flowering had begun on the SNG and SNG/BPF treatments in heated crop, with first harvest on 30 September 2003. Fruit matured earlier (approx 1 week earlier) on both the SNG and SNG/BPF treated plants in the heated crop. It was later noted that in all systems the SNG and SNG/BPF treatment plants had a continual advancement of 1 - 2 weeks in flowering and fruit set over the control plants.

Treatment differences in plant establishment and flowering advancement were more notable in the unheated media and NFT crops than in the heated crop. Higher flower numbers were also noted on the SNG and BPF treated plants. Differences in foliage growth and flower production became less noticeable in all crops as the season advanced and plants obtained full size development. It appears that during the early establishment phase, the initial soak of the entire plants in SNG and early foliar applications of SNG and BPF assisted plant nutrient uptake when root uptake was prevented until sufficient new root tissue had formed on the plants and leaf area was limited. Foliar fertilisers are known to have a significant effect where root systems have been damaged or compromised and are unable to take up nutrient ions - such as in establishment from field grown runners.

3.2 SNG and SNG/BPF Treatment effects on fruit yields

While there were differences in yield patterns over the 7 months of harvesting from the various hydroponic systems, the figures for total yield for each crop are given in Figures 1 - 3. Total yield (grams per plant) for the season (9 months) averaged from 381 g plant to over 1600 g per plant.

Figure 1 shows the total yield per plant after 4 months of harvesting for the heated NFT crop. The SNG treatment had the highest yield of 702 g per plant, while the BPF treatment had a slightly lower yield of 646 g per plant. The control treatment had the lowest yield of 381 g per plant. Production from this crop peaked in December (Summer).

Figure 2 shows the total yield per plant after 6 months of harvesting through the late spring, summer and fall periods for the unheated media grown crop. Strawberry crops have been shown to perform better in media based hydroponic systems as this data shows. As with the heated NFT crop, the highest yields after 6 months of harvesting were obtained from the SNG treatment with 1634 g per plant, followed by the SNG/BPF treatment with 1258 g per plant. The control treatment yielded 704 g per plant after 6 months. The yield over time graph (Figure 4) shows that during the early harvest dates, through November-December, the SNG and BPF treatment produced much greater earlier yields than the control plants which did not come into full production until Jan-Feb 2003. This demonstrates not only the advancement in plant growth but also in flowering and fruit development from the SNG and BPF treated plants. A similar percentage yield increase with the SNG and BPF crops can be seen in the unheated media crop and the heated NFT crop.

Figure 3 shows the total yield per plant after 5 months of harvesting through the December to May 2003 period for the unheated NFT crop. As with the unheated media grown crop, early yields were much greater in the SNG and BPF treated plants. This crop produced the highest yield figures from the SNG/BPF treatment with 1132 g per plant after 5 months of harvesting. The SNG treatment produced 712 g and the control treatment 392 g per plant.

Yield differences from the three different production systems - the heated NFT, unheated NFT and Unheated media based crop demonstrated that in this case the media based hydroponic system produced the highest yields. It was also found that irrespective of the system of production or application of greenhouse heating, the SNG and SNG/BPF treatments produced substantial increases in yield over the control crop and that much of this increase was in the early harvest dates. Control plants which received no foliar treatments, tended to produce similar yields per plant - of around 385 g per plant over a 5 - 6 month harvest period for the NFT crops which would be considered a moderately low to average yield for a winter planted strawberry crop under New Zealand conditions. Control plants were notably slower to establish after planting out in mid winter, despite the application of heating in one crop and foliage re growth was also slower in these plants. This obviously had an affect on early and total yield from these plants over the 9 month growing period. This demonstrates the importance of rapid establishment of pre chilled strawberry runners into hydroponic systems . The SNG and SNG/BPF treated plants produced higher early and overall yields, in some cases more than a 100% increase in total fruit yield was noted. This increase in total yield from both the SNG and SNG/BPF treatments was the result of not only significantly larger individual berries, but greater fruit numbers as well, indicating that the foliar treatments assist with overall plant establishment and foliar development but also flower production and fruit growth.

Figure 1

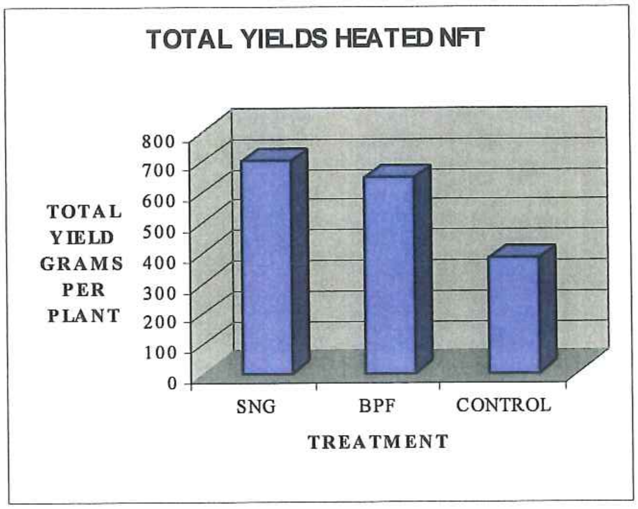


Figure 2

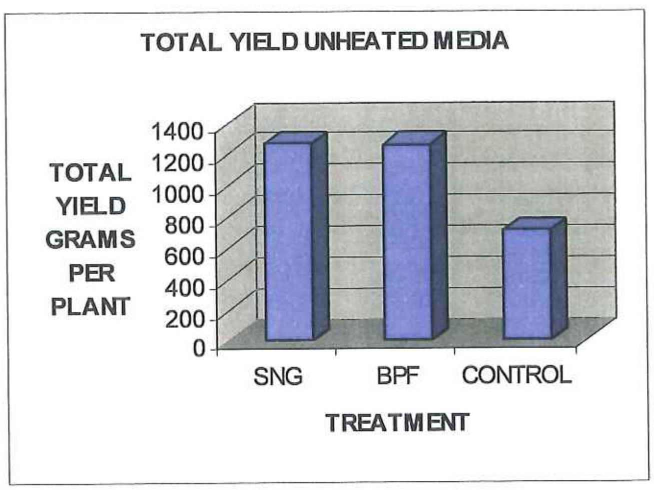
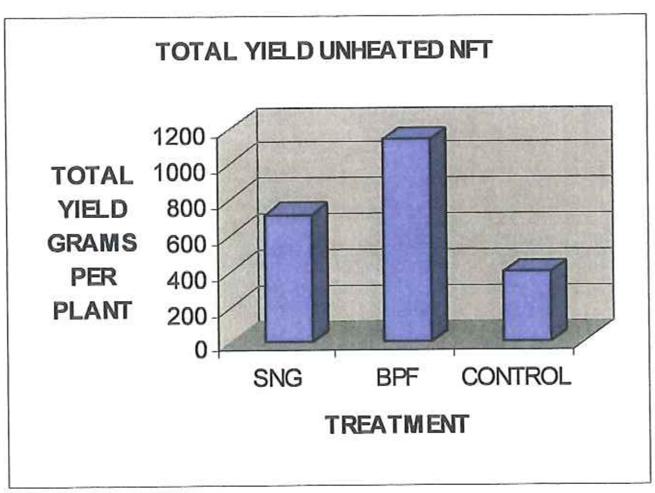


Figure 3



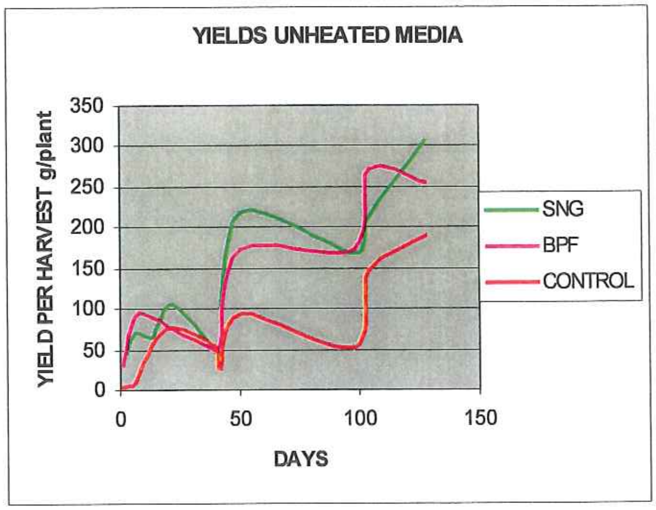


Figure 4

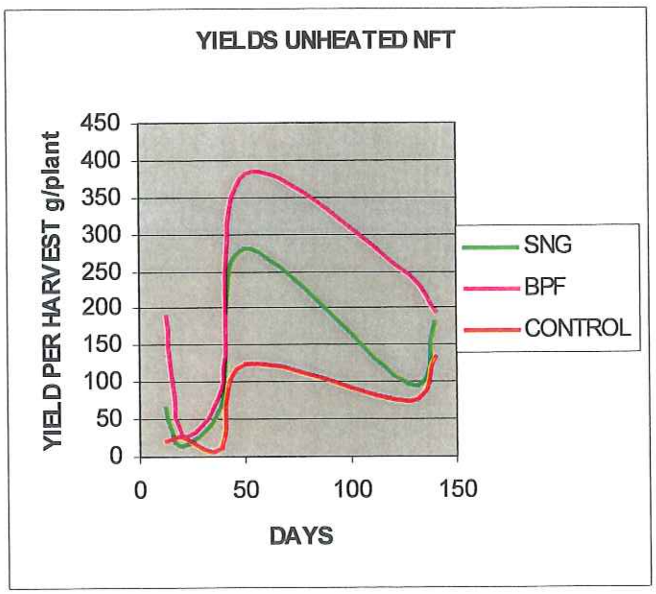


Figure 5

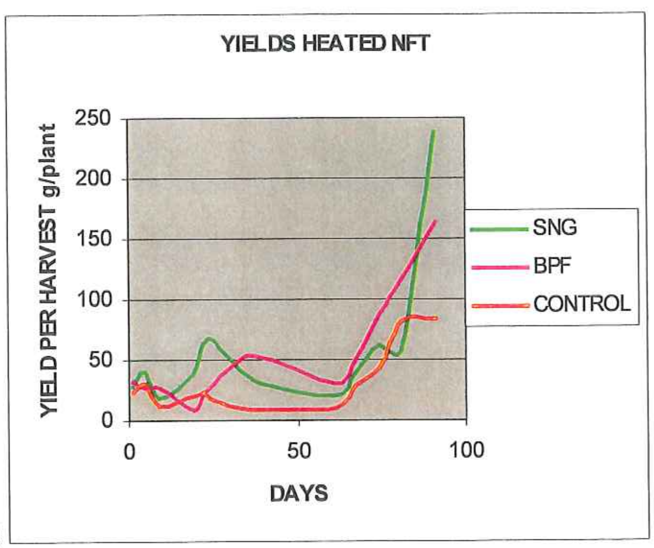


Figure 6

3.3 SNG and SNG/BPF Treatment Effects on fruit brix levels

Brix levels were analysed from 7 separate harvest dates from early December 2002 (Summer) to late April 2003 (Fall), as shown in Figure 7. While differences in brix levels at each harvest date exist, the overall trend is for the SNG and SNG/BPF fruit to have significantly higher brix levels than the control fruit. The differences in brix levels between harvest dates is likely to be due to changes in environmental conditions as the seasonal light and temperature levels changed. Figure 8 shows that when all the 7 harvest dates are averaged, the SNG treatment has an average brix level of 7.66, the SNG/BPF treatment 7.51 and the control treatment 7.10. This indicates that the SNG and SNG/BPF foliar treatments improved fruit brix (sugar) by a discernible level.

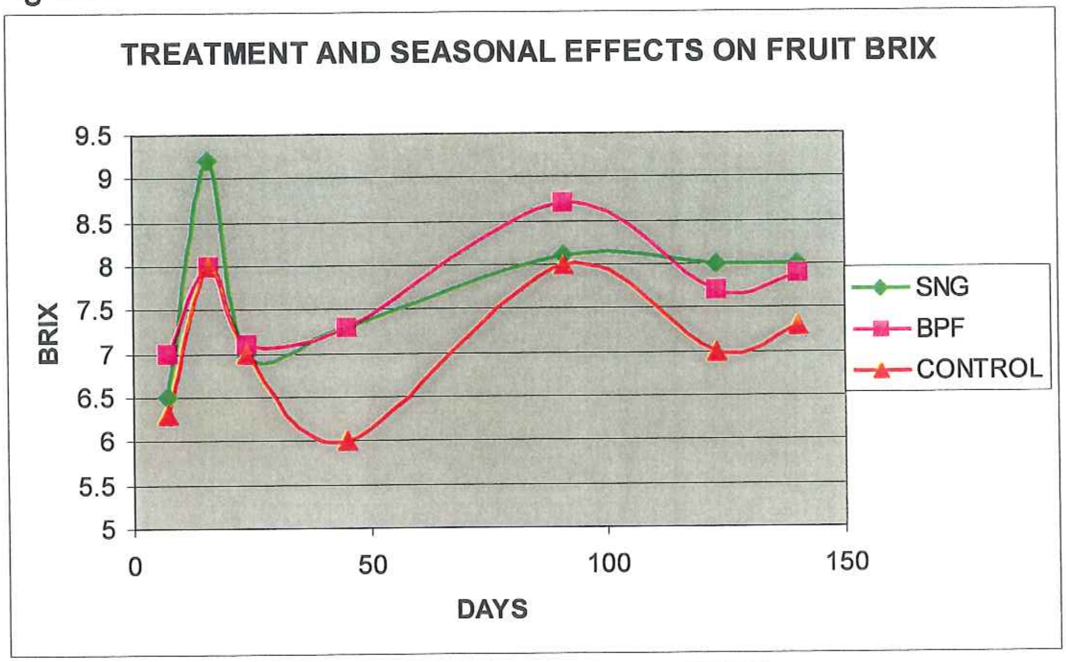
3.4 SNG and SNG/BPF Treatment effects on fruit dry matter levels

Figure 9 shows the differences in fruit dry matter percentage levels from two harvest dates (January and April 2003). Differences in dry matter percentages between the two harvest dates are likely to be due to growing conditions and crop fruit loading at the time of harvesting. At both harvest dates, the SNG/BPF fruit had the higher dry weight, followed by the SNG treatment, although the difference was more pronounced at the April assessment. At both harvest dates, the control fruit has the lowest dry weight percentages.

3.5 SNG and SNG/BPF Treatment effects on fruit ascorbic acid (Vitamin C levels)

Figure 10 shows the ascorbic acid values for each harvest date, while figure 11 shows the average ascorbic acid values for the season. While there are differences in ascorbic acid levels at each harvest date, when averaged over the entire season, the SNG and SNG/BPF treatments show no significant difference between each other (SNG at 360ppm and SNG/BPF at 357ppm). However both the SNG and SNG/BPF treatments are significantly higher than the control treatment which averaged 304 ppm of ascorbic acid over the 7 harvest dates (Figure 11). This represents a 16% increase in ascorbic acid levels between the treated and untreated fruit samples.

Figure 7



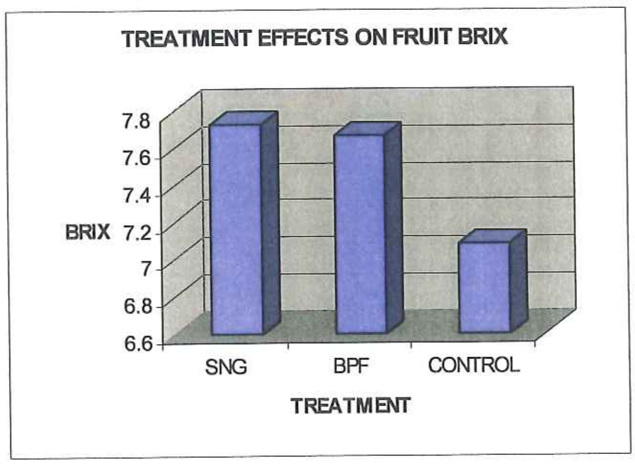


Figure 8

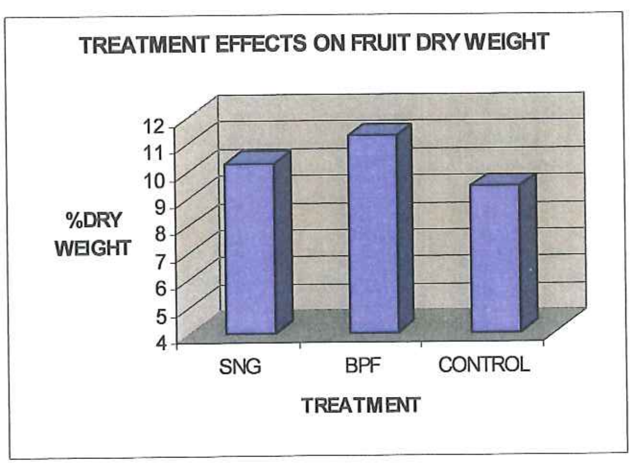


Figure 9

Figure 10

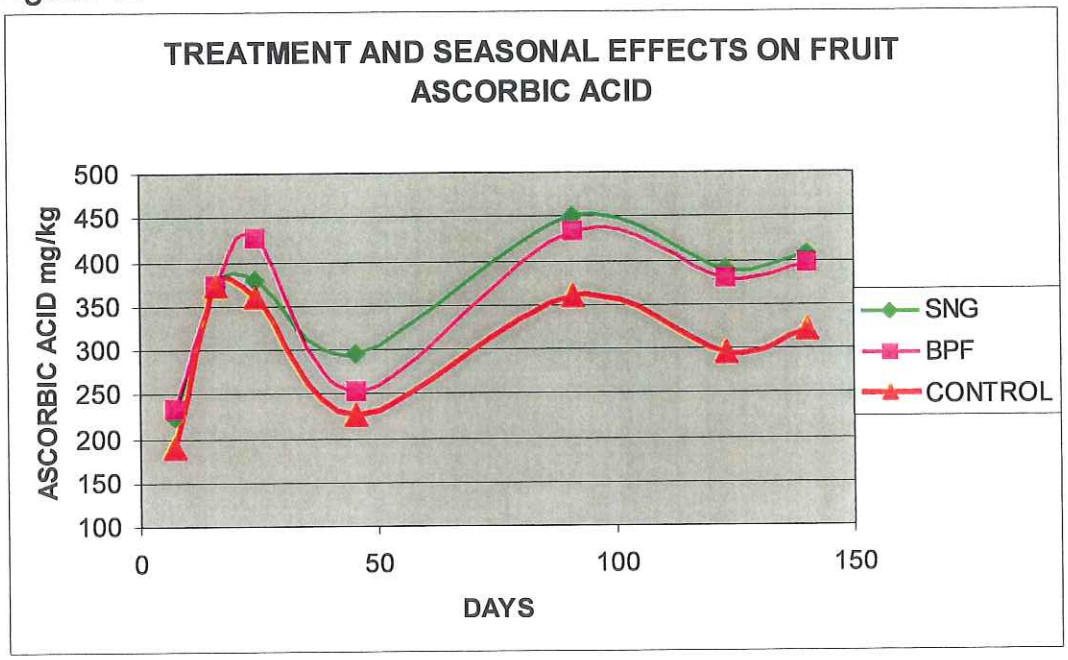
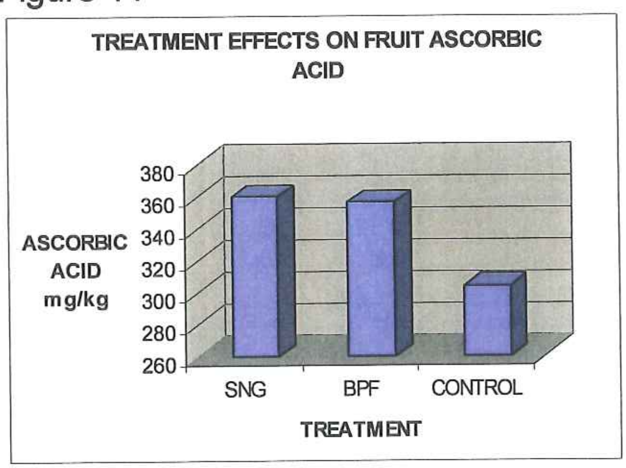


Figure 11



3.6 SNG and SNG/BPF treatment effects on fruit shelf life

Fruit shelf life assessment was carried out on two separate harvest dates (Jan and April 2003) and the results averaged. Fruit from all treatments and harvest dates softened quickly when stored at room temperature (20 $^{\circ}$ C), however the control fruit demonstrated the most rapid fruit tissue breakdown with softening occurring within 4 days. The SNG and SNG/BPF fruit softened to unacceptable quality within 6 days. The slower rate of fruit softening shown in the treated fruit is related to the higher percentage dry matter in these fruit samples and greater degree of fruit firmness. The control fruit were also more prone to developing post harvest fungal rots during storage.

3.7 SNG and SNG/BPF treatment effects on foliar mineral levels

Table 2 shows the results of the foliar mineral analysis from each treatment. Note: Leaves were surface washed after harvesting to remove any residue from the treatment applications. Values for most of the minerals analysed differed little between treatments, however since this was a foliar analysis only, it is possible that higher mineral levels may have been present in the fruit from the three different treatments.

Table 2. Foliar mineral levels by treatment

	Treatment		
Mineral	**SNG**	**SNF/BPF**	**CONTROL**
Nitrogen %	3.0	3.1	2.9
Phosphorus %	0.99	1.1	1.0
Potassium %	3.7	3.8	3.4
Sulphur %	0.27	0.27	0.35
Calcium %	0.99	0.97	0.99
Magnesium %	0.41	0.44	0.49
Sodium %	0.08	0.06	0.02
Iron ppm	378	466	382
Manganese ppm	830	820	800
Zinc ppm	70	65	40
Copper ppm	4	5	4
Boron ppm	41	39	40

TREATMENT DIFFERENCES - NOVEMBER 2002

SNG Treatment plants - unheated NFT crop, November 2002 at the time of first harvest.

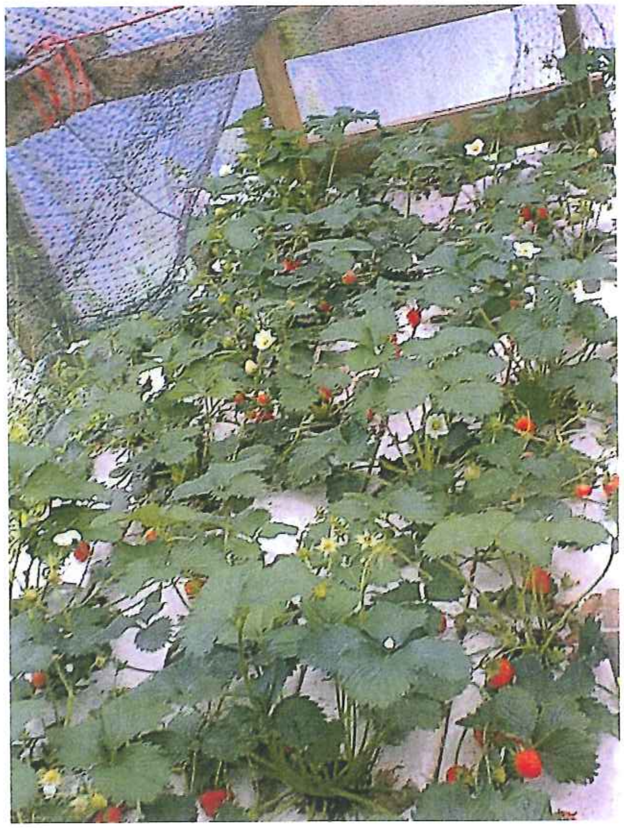
SNG/BPF Treatment - unheated NFT crop, November 2002 at the time of first harvest.

Control treatment plants - unheated NFT crop, November 2002. Note less flowering and slower fruit development than the SNG and SNG/BPF treatments.

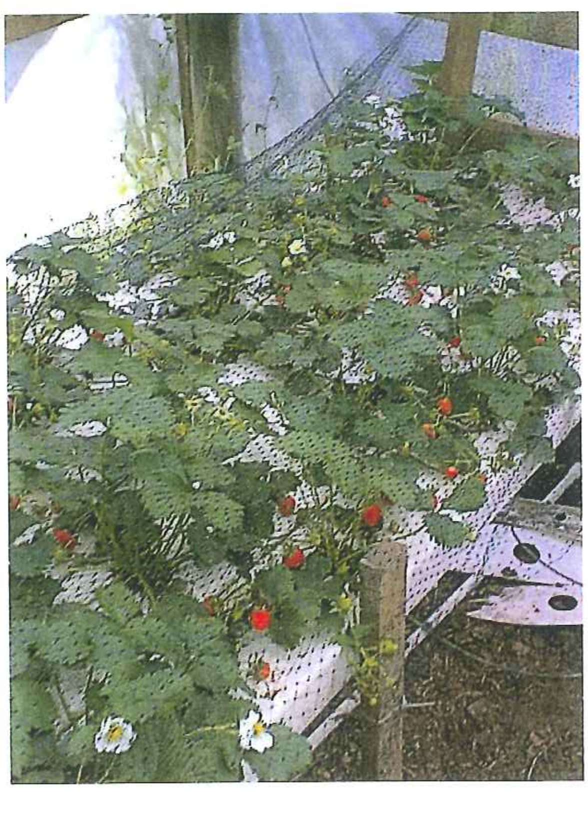
SNG treated, NFT grown hydroponic strawberry fruit developing - November 2002

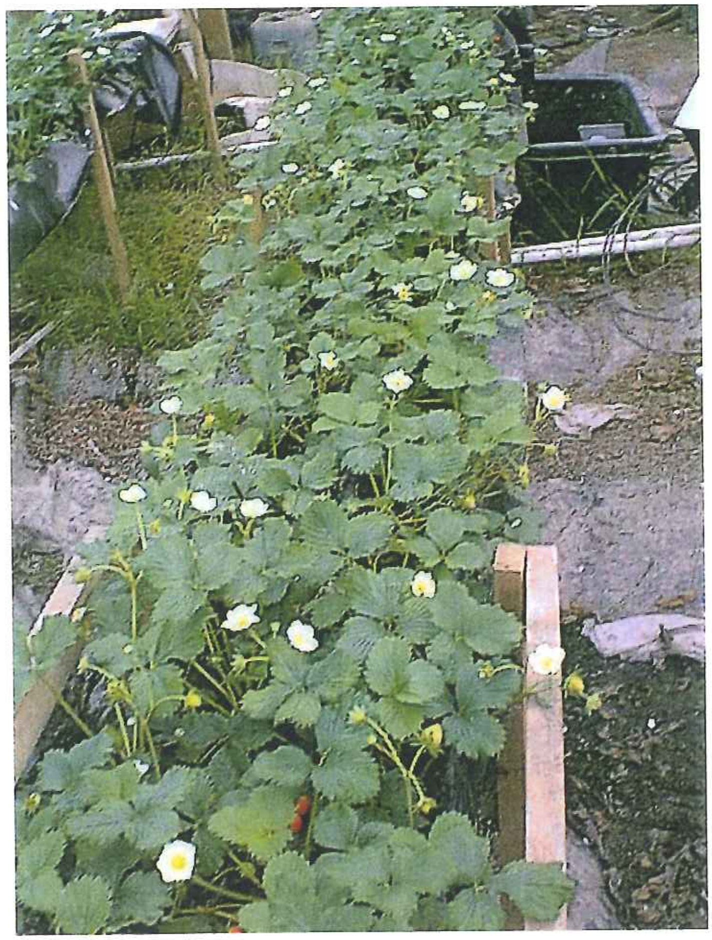
Trial fruit reaching harvest stage, November 2002

Unheated NFT crop at the time of first harvest - November 2002

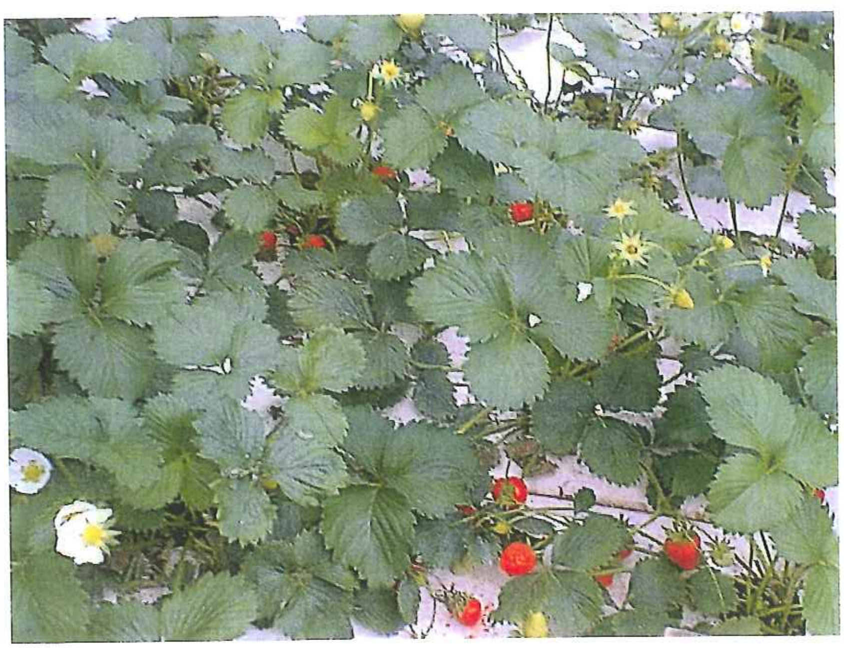


Part of the unheated NFT crop, December 2003, bird netting installed - below



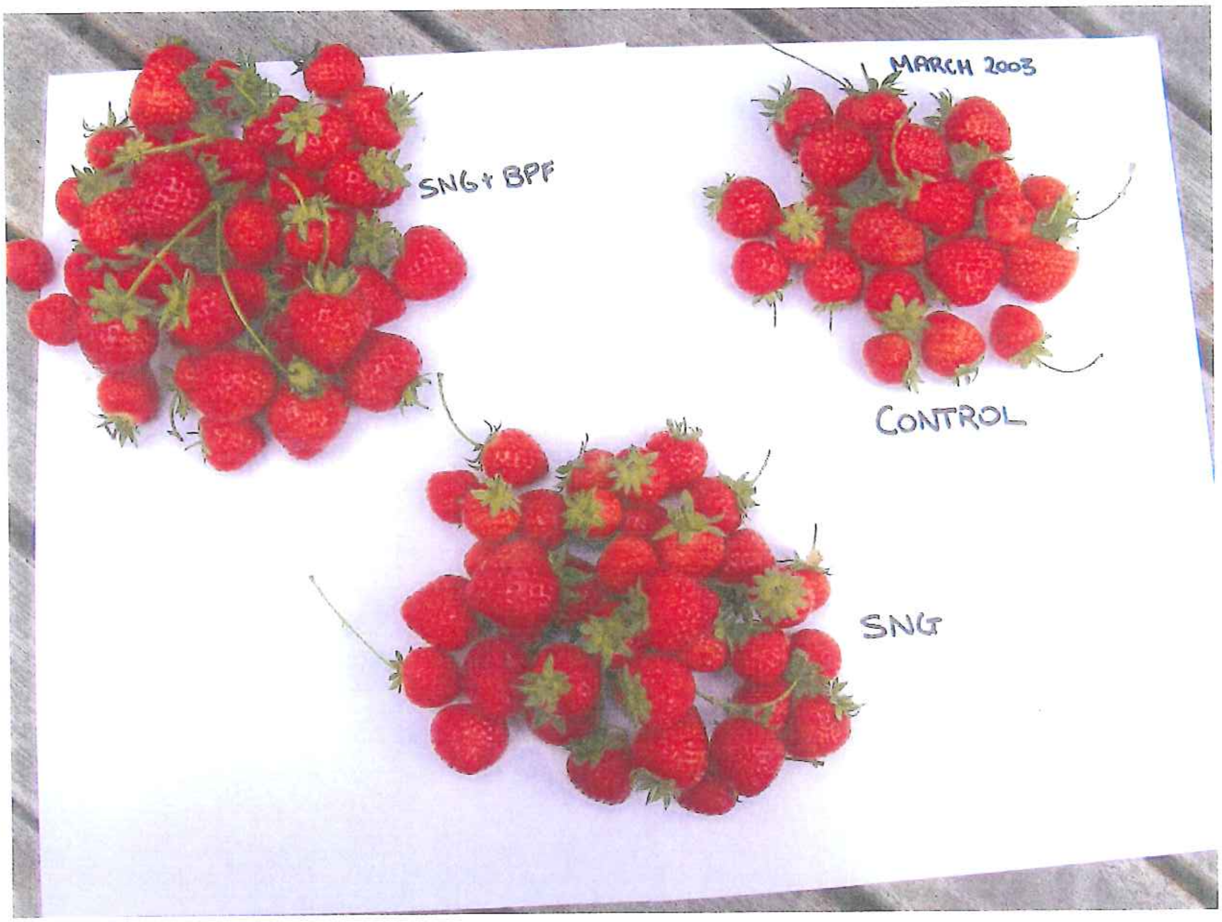


Media system crop growth in December 2002 (above)
Unheated NFT system crop growth in December 2002 (Below)



Media based crop in Jan 2003

Typical fruit harvests from the Media grown crop in early 2003



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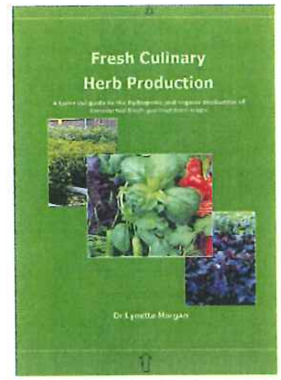

CONCLUSIONS AND SUMMARY

4.0 Conclusions and summary

Foliar fertilisation has been proven in previous studies to increase not only yields, but also fruit quality of hydroponically grown crops such as tomatoes, snow peas and lettuce as well as a number of soil grown fruiting plants. In this trial it became apparent at an early stage that the pre-chilled, bare rooted, field grown strawberry runners benefited significantly from the foliar application of both SNG and SNG/BPF treatments, at a time when root based nutrient uptake was severely compromised by the lack of live root tissue. Even after several weeks of establishment, the growth (both foliar and root) advancement on the foliar treated plants was notable. During this time when the plant is developing a new root system, leaves and flower buds, there is a high nutrient demand within the plant which is not met until the root system has developed sufficiently for rapid mineral uptake. It is likely that during this stage the SNG and SNG/BPF treatments have the greatest advantage in supplying mineral ions through the developing foliage while the root system is still establishing. The earlier flowering and more rapid fruit development noted on the treatment plants is likely to be an effect of ongoing foliar uptake of mineral ions as well as the larger and more developed plants noted in the SNG and SNG/BPF treatments. Larger, established strawberry plants with a greater leaf area at the time of fruit set and early fruit development have been proven to produce larger berries and higher long term yields than smaller, less developed plants and this is likely to be partially the reason for the significantly greater yields obtained from all treatment plots.

Strawberry plants produce a high fruit load and overall fruit yield for the average size and leaf area of each plant, thus the demand for both photo assimilate and nutrients is particularly high for this crop. High fruit loading puts pressure on the root system to absorb sufficient minerals for maximum fruit quality and yields. However root systems in strawberry crops are often compromised in both soil based and hydroponic systems as they are prone to a number of root rot pathogens, damp conditions, lack of oxygen and general root restriction in growing beds. At the time of heaviest crop loading, strawberry roots often experience the same `root die back' of older roots that has been found to occur in other crops such as tomatoes. This in turn can limit nutrient uptake at a time when maximum levels of nutrients need to be imported into the fruit tissue. Under these conditions it appears that foliar fertilisation on a regular basis, assists the plant to provide nutrients to not only the developing fruit, but also new foliage and roots.

The strawberry is a small compact plant, so it is assumed that foliar fertilisation on a regular basis not only ensures a good coverage of a small leaf area, but also means absorbed minerals need only be transported a short distance within the plant, from leaf to adjacent fruit.

Treatment with the SNG foliar micro nutrient complex has previously been proven to 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 fruit quality in terms of dry matter percentage, firmness, shelf life, sugar (brix levels) and also ascorbic acid levels.

Both SNG and SNG/BPF had the effect of advancing flowering and increasing the number of flowers and hence berries per plant - this could be an effect of improved plant nutrition, assisting the plants to absorb minerals in an environment where root uptake could be limiting. However there may be other as yet unexplained reasons why the SNG and BPF complexes benefit plant physiological processes and assist flower production and fruit set.

Foliar fertilisation with the SNG micro nutrient complex and Bill's Perfect Fertiliser in hydroponically grown strawberry crops in a number of production systems, both NFT and media based has proven to not only greatly assist with initial plant establishment and development, but to also advance flowering and early yields as well as having a beneficial long term effect on total fruit yields and compositional quality.

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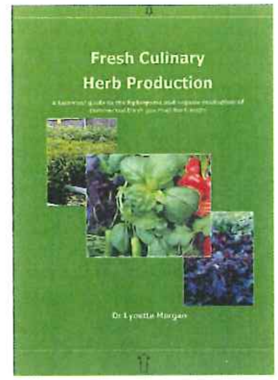

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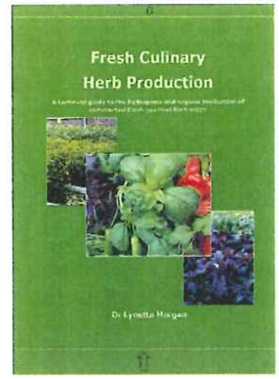

APPENDIX ONE

Strawberry Nutrient Formula

APPENDIX ONE

STRAWBERRY 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

Nitrogen (N) 155 ppm
Potassium (K) 256 ppm
Phosphorus (P) 70 ppm
Magnesium (Mg) 49 ppm
Calcium (Ca) 126 ppm
Sulphur (S) 65 ppm

Micro Nutrients in ppm

Iron (Fe) 6.90 ppm
Zinc (Zn) 0.25ppm
Boron (B) 0.70ppm
Copper (Cu) 0.07ppm
Molybdate (Mo) 0.05ppm
Manganese (Mn) 1.97ppm

Nutrient salts by Weight

Stock soluton volume 100 litres, dilution rate 1:100 to give an EC of 1.70, pH of 5.8, TDS of 1190.

Part A

Calcium Nitrate 6291.3 g
Potassium Nitrate 2215.3 g
Iron EDTA 500 g

Part B

Potassium Nitrate 2215.3 g
MonoPotassium phosphate 3335.8 g
Magnesium sulphate 5003.7 g
Manganese sulphate 80 g
Zinc Sulphate 11.013 g
Boric acid 39 g
Copper sulphate 3.022 g
Ammonium molybdate 1.022 g

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