Soilless Cultivation For Table Top Strawberry

Contents

Tyfu Cymru: A Horticultural Manifesto for Wales

The Tyfu Cymru project's goal is to build the capacity and capability of the Welsh horticulture industry. Working with supply chain partners it will prepare growers and producer owned horticulture companies across Wales to adapt to future environmental challenges and position them to capitalise on market opportunities for business development and growth. This project will support the Welsh Government to realise its ambitious objectives for growth and rural regeneration through the innovative and sustainable development of the horticulture industry in Wales. Led by Lantra, working with key partners Puffin, Glyndwr University and ADAS, with funding from the Welsh Government Cooperation and Supply Chain Development scheme, it will provide a blend of strategic leadership, skills development, training and support tailored to the needs of the industry. It will draw on evidence gained from expert horizon scanning and analysis of business needs, and it will demonstrate the social, environmental and commercial benefits for businesses and the Welsh economy.

Is this your opportunity to develop your business? The grower toolkit highlights the benefits and practical tips for soilless growing and how using innovative methods with the right support can take your business forward.

What we offer:

- Funded innovative training and skills development
- A horticulture talent pool programme
- Supply chain and cluster support
- One stop knowledge hub offering an industry voice.

If you would like to find out more about any aspect of commercial growing and how to develop your horticulture business please contact Tyfu Cymru via email at **Tyfucymru@lantra.co.uk** or see what we're doing by keeping up with Tyfu Cymru on social media: find us on Facebook at **tyfucymrugrowingwales**, or on Twitter **@TyfuCymru.**

About This Grower Guide

Growing crops without using soil is widely practiced in horticulture as an efficient and cost effective method for the production of high throughput, high value edible crops. Control and the proportion of marketable yield can be further enhanced by using soilless systems under plastic or glass growing structures. Covering the crop not only "keeps the weather off" but with appropriate site logistics can integrate the use of lighting and heat to extend the growing season, and with sufficient investment realise all year round growing. The Agricultural Land Classification (ALC)[1] of Wales defines the top three grades (1-3a) as the 'Best and Most Versatile' agricultural land, and accounts for 7% of the total land in Wales. Soilless cultivation also removes any limits on cultivation imposed by soil type or the availability of space, offering a chance for growers to use a new way of growing to increase and diversify their outputs. As such, soilless cultivation has been identified as a key innovation that could be exploited to promote development of the horticulture sector in Wales. The methods used for soilless cultivation are numerous and can be tailored to suit new or existing holdings. This document has been prepared to provide summary information around soilless cultivation to help promote the uptake of new growing methods in the Welsh horticulture sector. How to establish soilless cultivation is outlined, along with advice on integration into existing production and marketing routes so that growers can implement selected techniques as part of their enterprise.

[1] http://lle.gov.wales/catalogue/item/PredictiveAgriculturalLandClassificationALCMap?lang=en

1 Introduction to Soilless Cultivation

Until 1997, strawberry production in the UK was relatively constant (**Fig. 1.1***Error! Reference source not found.*), although berries where of variable quality and picked mostly during June and July; of which some 25% was marketed through supermarkets[2]. In 1997 the three year average yield was 8.6t/ha, representing 52% of the soft fruit sector, increasing to 23.0t/ha and 72% of the sector in 2015[3]. In value terms, as of 28th April 2016, annual strawberry sales totalled £564 million, accounting for over 51 percent of the total value of soft fruit sales, which reached a record high of £1.1billion[4]. At the present time, soft fruits represent 22% of all consumer fruit purchases in the UK[2], showing strong consumer demand for strawberries.

Through innovations and investment, UK growers have managed to keep pace with a 153% increase in consumer demand over the last 20 years[5]. With only 75-80% market penetration, underserved markets, as well as discount supermarkets seeing a 40 to 50% growth in sales over the last two years, there is still considerable potential for increasing production[6].

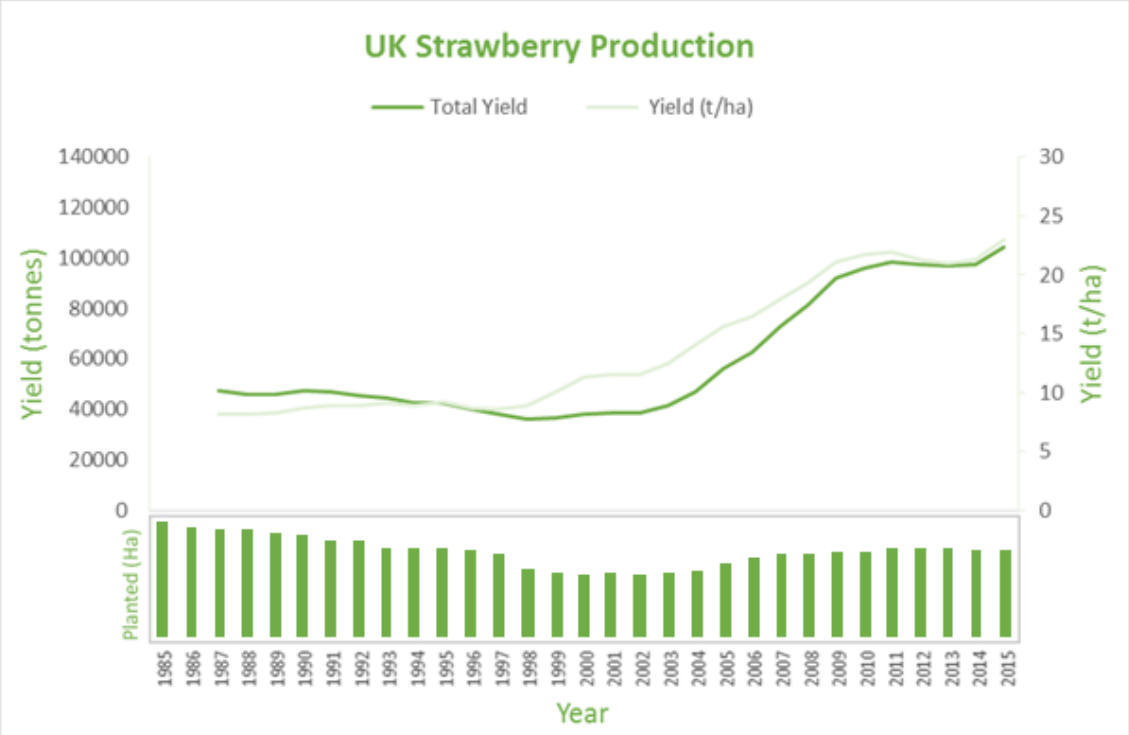

Fig. 1.1: *3-Year Moving Average of Domestic Strawberry Production[3].*

[2] British Summer Fruits (2017). Seasonal Labour Report: The Anderson Report - The Impact of Brexit on the UK Soft Fruit Industry. Available from: www.britishsummerfruits.co.uk/media/TheAndersonReport.pdf

[3] Defra (2017). Horticulture Statistics (Dataset – 2016). Available from: tinyurl.com/ycqsajx8

[4] Seasonal Berries (2016). The British Strawberry Season Begins as Consumer Demand for Berries Increases.

[5] British Growers Association (2017). Producer Organisations after Brexit - Competitive, Sustainable, Trusted and Resilient Fruit and Vegetable Production.

[6] Seasonal Berries (2017). How Brexit Could Crush Our Soft Fruit Industry. Available from: tinyurl.com/y79fdzy8

Although domestic producers are meeting almost 100% of UK demand between May to September, this only represents 69% of total annual demand[3]. With Dutch and Belgian growers now picking year round[7], there is potential for UK growers to increase upon the 10% of soft fruits currently grown under glass to increase our capacity to meet national demand.

1.1 The Table Top System

The most convenient way to grow strawberries with minimal capital outlay is in the soil. This relies however, on good quality soil, with little pressure from soil borne pests and diseases. Crops grown in soil are commonly grown within a rotation, with chemical soil sterilisation practiced where rotations are impractical. However, approval of several of the chemical products used for soil sterilisation such as methyl bromide and chloropicrin have been or are being removed as part of the ongoing EU review (EC) No.1107/2009 on Pesticide registration[8]; prompting a shift toward soil-less or substrate systems.

Currently, 55% of all strawberries are grown in substrate, with 45% still grown in soil[2]. Strawberries are grown in substrate filled bags or troughs on low trellis systems, known as "table tops", or placed on the ground on raised soil beds and covered with polythene to exclude weeds and prevent the plants roots coming into contact with the soil. As experienced pickers become more difficult to source, cultivation in soil becomes more problematic, and the costs of employment increase, improving picker efficiency becomes vital to grower profitability.

Table 1: *Cost of labour (Soil Grown vs. Table Tops). Adapted from The Anderson Report [2] and BGA Report (2017)[6].*

Year	Strawberry (£/Tonne)	Median Labour (Hours/Tonne)	Labour (£/Hour)	Labour (£/Tonne)	Labour (% of Price)
Soil Grown					
1999	3,000	160	3.60	576	19
2015	3,000	160	8.00	1,280	43
Substrate Grown (Tabletop)					
2015	3,000	120	8.00	960	32

Between 1999 and 2015, labour costs increased by 222%, whilst the price of strawberries remained constant over the same period (***Table 1***). The introduction of table top cropping systems not only ensure even production, but also an average saving of 20-25% in labour requirements (120 hours median labour requirement for substrate grown strawberries versus 160 hours for soil grown berries[2]), representing an overall cost saving of 11% (***Table 1***).

Although the greatest efficiencies in hydroponic systems can be achieved in recirculated systems, their use for the production of strawberries represents an unacceptable level of risk for growers due to the potential rapid spread of water borne oomycetes including *Phytophthora* spp. This ensures that strawberries are grown in irrigate to waste systems such as table tops, where excess feed solution is allowed to drain to the grass or bare ground beneath or collected and reused in other areas of the grower holding, rather than recirculated.

A number of variations of table top systems exist; each appealing to different growers based on the size of their operations and preferred level of control. The support system consists of gutters or wires

[7] Seasonal Berries (2014). UK Set For Early, Sweet Bumper Strawberry Crop. Available from: tinyurl.com/ycg8nbbm

[8] Produced by ADAS on behalf of the Environment Agency (2012): Report 26477 - Diffuse Pollution: Best Practice Advisory Programme for Soft Fruit in the South East Region.

raised 1.5m above ground level on support trellises, allowing for easy picking and free air movement around the berries; reducing incidences of botrytis. (**Fig. 1.2:** Open air table top strawberry production with grass beneath)[8].

Fig. 1.2: *Open air table top strawberry production with grass beneath.*

Gutter systems are often more durable, allowing for easy placement of loose substrate and collection of runoff, for monitoring and periodic analysis. Wire systems are normally favoured by growers looking for a lower cost solution; also those not intending to collect runoff, other than for periodic analysis. All table top systems are supplied with water and nutrients by trickle irrigation with 2 to 4 drip emitters or pegs per substrate unit (1-1.2m substrate bags, or loose medium of equal length)[8].

1.2 Protected Table Top Systems

In an effort to further increase the productivity of table top systems, growers are covering crops with polytunnel structures, with the majority favouring temporary Spanish or French tunnels. This helps drive growth through elevated temperatures, although, the primary effect of the cover is to minimise fruit spoilage. Previously, berries could only be picked in the field and stored when fruits were dry; with the advent of tunnels and an upsurge in the share of strawberries grown under glass, the risks associated with direct rain damage have been eliminated.

A standard 8.5m wide tunnel accommodates 5 rows of table tops, with the paths between successive trellises used for crop management operations; including crop observation, pest and disease control, picking, irrigation management and grass mowing as necessary. Large scale polytunnel sites must now receive planning permission in many regions which is leading growers to move towards the adoption and development of more permanent production sites, where services such as a clean water supply, electricity, proximity to pack houses, and road access are also available.

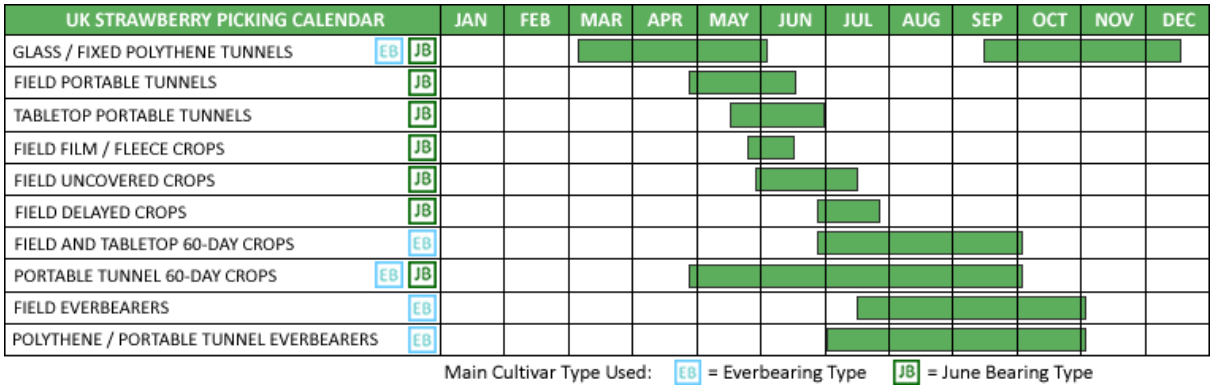

Fig. 1.3: *Season extension using a range of production systems. Adapted from: HDC Factsheet 12/10*[9]***.***

[9] Raffle S., Irving R. and Moore G., (2010). HDC Factsheet 12/10: Extending The UK Strawberry Season Using a Range of Plant Types and Growing Systems.

Table top strawberry production can be split into two main types; June bearing (single fruit crop) or everbearers (continuous fruiting). Without providing the crop with heating, June bearing varieties will fruit naturally from May until July, and everbearing types from June to November with a combination of forcing and delaying techniques (**Fig. 1.3**). Most holdings will have combinations of these crop types to allow scheduling of strawberry production from late April to October or even November. It is also possible to plant cold stored June bearers from April onwards as a programme instead of everbearers, however this method is often problematic and results in reduced yields from prolonged cold storage of runners (see section 2.3 Plant Material).

The earliest crops are generally harvested under glass in southern England in early April although additional heat and night-break lighting can bring crops into fruit as early as March, with the latest crops fruiting up to late December (**Fig. 1.3**). The season continues under closed fixed polythene tunnels, followed by field-grown crops under French and Spanish tunnels, lay-flat fleece or polythene film. The traditionally grown, unprotected field crops then become available for PYO and direct retail in June and July[9].

The tunnels are necessarily flexible to allow the plastic to be removed; providing exposure to cold 'chilling temperatures' required during the winter periods to maximise flower set and the productivity of crops grown over 2-3 seasons. The cropping environment is easily managed through the venting of tunnels to optimise temperature and humidity, as well as, the use of side skirts and door ends to achieve the earliest harvests.

Fig. 1.4: *Drip irrigated glasshouse trough system.*

Some growers with existing structures, or those who favour greater control will choose to grow under glass; commonly with compacted earth covered with gravel or geotextile beneath the crop (**Fig. 1.4**). Glasshouses also allow for gutters to be suspended from the roof, giving the grower greater flexibility over their production space and more efficient and effective cleaning of the greenhouse. Glass will extend the season from the start of April at the start of the year and to early December at the end, longer if heat is given.

2 Hydroponic Growing

2.1 Irrigation Water

There is a strong correlation between optimising irrigation water and nutrient use, and overall financial returns[8]. An understanding of the quality of the water sources available to you will help determine which are most suitable. The use of mains water will afford you consistent quality, however using mains water as your primary water source may prove to be prohibitively expensive.

When growing in soil-less media, understanding the basic chemical and biological content of irrigation water helps in identifying crop problems, the correct calculation of fertiliser stock solutions, and optimisation of substrate pH. This should be done before irrigation planning, to ensure potential

problems are avoided. Hand-held equipment are available for monitoring E.C. and pH during the production season, but a full laboratory water analysis is recommended at least every 12 months for substrate-grown crops.

Substrate Available Water (AW)

What is available water?

The amount of water present after the medium has been saturated and allowed to drain, less the amount still present at permanent wilting point. A growing medium may have a low available water capacity because it has low total porosity (see section 2.2), there is poor interconnectivity between pore spaces or conversely the pores are relatively large, well connected and water drains rapidly under the influence of gravity. Whilst AW can be influenced by particle size it can also be encapsulated within plant / moss cell structures such as those found in peat substrates.

What effect does it have?

The ability of a plant to extract water from a growing media is critical for plant growth. A growing media should have a relatively large amount of available water to overcome potential water loss through evapotranspiration. Time taken for plants to wilt is not necessarily proportional to the available water and as such different media either alone or in combination require different water management strategies to achieve optimal plant performance.

Low AW: The plant is unable to extract enough water from the medium for growth, resulting in wilting and whole plant loss.

High AW: The plant could become waterlogged if it is watered too much and/or too frequently. This can be overcome by careful irrigation management.

2.1.1 Contaminants

The main microbiological contaminants of water are fungal spores, such as *Phytophthora* spp. (the cause of red core and crown rot diseases in strawberries) and bacteria, such as E. coli (of significant concern for overhead irrigation). Irrigation water should be checked to ensure it has acceptably low levels of contaminants before use. There are several chemical, biological and physical techniques which can be used to purify the water if such contaminants are present, for example UV light treatment[10].

2.1.2 pH and Alkalinity

The level of bicarbonates (principally calcium) in the water determines its hardness. Hard water, which with a high bicarbonate content, occurs in areas where the underlying rocks are calcareous and may be either mains, well or borehole in origin.

High pH water, which may not necessarily correlate to the calcium bicarbonate content, can also reduce the availability of certain nutrients such as iron. Whilst it is not practical or economic to consider acidification for soil-grown crops, for hydroponically grown crops, alkaline feed water must be acidified; this can be done by using acidifying fertiliser mixes or the addition of a separate acidifying agent (if bicarbonate levels exceed 150 mg/l)[10].

[10] Atwood J. and Perry M., (2007). HDC Factsheet 06/07 Principles of Strawberry Nutrition in Soil-Less Substrates.

In areas of very soft water, there may be the opposite problem of a very low levels of calcium, when additional calcium must be applied in the feed for fruit firmness.

Substrate pH

What is pH?
A measure of the relative concentrations of hydrogen and hydroxyl ions in a growing medium suspension. It is expressed on a logarithmic scale from 0 to 14.

What effect does it have?
The pH can affect the availability of macro and micro nutrients to plants in the growing medium.

Low pH: A very low pH can cause macronutrients such as N to become less easily available, which may result in older leaves exhibiting deficiency and yellowing.

High pH: Selected micronutrients, such as iron, can become unavailable to plants resulting in young leaves turning white.

2.1.3 Electrical Conductivity

The electrical conductivity (E.C.) is a measure of the total salt content of the water, and is how the industry monitors the total amount of nutrients added in predetermined ratios within the selected crop, making it a key management factor.

The main contributors to high conductivity levels are nitrate, chloride and sulphate ions. A high conductivity due to high chloride levels can be particularly restrictive, as it limits the amount of feed that can be added to the water. Water with a naturally high E.C. could give rise to a build-up of salts in the media leading to potential root damage.

Municipal water has a typical E.C. of approximately 500 mS/cm (milliSiemens per cm). Rainwater is generally pure, with low conductivity and pH and a very low calcium level. Borehole water in coastal and Fenland areas may have a high conductivity due to salt water contamination.

Substrate E.C.

What is Substrate E.C.?
Substrate E.C. provides a measure of the total soluble salt content of a growing medium. Soluble salts present, dissociate into positively or negatively charged ions; E.C. is proportional to the electric current flow between an anode (positive charge) and cathode (negative charge). E.C. is measured by a conductivity meter in a saturated extract or suspension in water and is commonly reported in units of µS/cm (microSiemens per cm).

What Effect Does it Have?
High EC: This can result in plant injury or loss, acting as a specific ion toxicity or by constrained osmotic water transfer into plant roots.

Strawberries prefer irrigation water with an E.C. of less than 1000 mS/cm; and water with a higher E.C. ideally avoided or diluted with other water sources. The recommended electrical conductivity

levels for hydroponic strawberries will vary depending on environmental conditions, growing systems and stage of plant development. In growing media a nutrient solution EC range of 1.4 - 3.0 mS/cm is recommended, with a minimum of 1.6 mS/cm at fruiting for best fruit quality[11]. Low EC readings lead to sub optimal growth, high EC's lead to small fruit. Substrate crops are seldom, if ever given water alone.

2.2 Substrates

Until recently peat and coir have been the industry standard substrates used in table top production systems. However, the use of peat as a growing medium is now in decline due to concerns over its sustainability. In comparison, coir is produced from the waste husks of coconuts, and is considered a renewable resource, and following its use as a substrate, may be utilised as a soil conditioner or composted.

The relatively inert and slight acidic nature of coir makes it ideal for hydroponic use as it does not affect the applied nutrient solution. Coir fibre has good porosity allowing good gaseous exchange in the root-zone. Its ability to absorb and retain large quantities of nutrients between irrigations means that less frequent irrigation events are required, and therefore less nutrient solution is lost through the crops' drainage allowance (see **2.5 Irrigation Management**).

Coir is typically blended with other substrates like woodchips, and is available in prepared slabs to be used as a loose substrate in gutter systems, or in bags with pre-cut planting and drainage holes for use in gutter or mesh systems.

Just as with irrigation water it is important for growers to sample their growing media prior to planting out. This should be done randomly; ensuring substrate structure, pH and nutrient levels are all satisfactory.

Substrate Air-filled porosity (AFP)

What is air-filled porosity?
The proportion of air filled pores after gravitational drainage from saturation.

What effect does it have?
Plant roots require an adequate supply of oxygen to maintain growth (respiration), but also discharge waste gases which include carbon dioxide and ethylene to the atmosphere. A growing medium must have sufficient pore space for the roots to remain aerated, but not to the extent that the plant is drought stressed. AFPs of 1025% are typical in growing media for pot grown plants, although the target values will be substrate and plant specific.

Low AFP: There are not enough air spaces present to sufficiently aerate the roots, resulting in root damage and potentially whole plant loss.

High AFP: The air spaces present are too large and the medium drains quickly. The growing medium will have to be irrigated frequently to prevent drought stress.

[11] Morgan L. (2005). Hydroponic Strawberry Production, ISBN: 0-473-10910-7.

2.3 Plant Material

The cultivation of strawberries in table top systems relies on a range of planting materials to cover the full spectrum of growing periods under protection. Plants can be sourced as cold stored runners (waiting bed, misted tip and A+ plants) or tray plants. Cold stored ('frigo') plants are carefully chilled to -1.8°C (when plants are fully dormant), and are often planted in spring or during gaps in cultivation, for programmed production 60 days after planting.

Cold stored plants are generally stored for 3 to 9 months, with larger crowned runners being favoured for extended storage periods (summer planting), as a decline in sugars and starch during prolonged storage is correlated with a decrease in number of flowers developing to anthesis and subsequent yield[12]. Many growers will source runners from either The Netherlands, Spain or USA, with some sourcing from within the UK. A list of potential suppliers can be found in section 6 of this toolkit. Strawberries are normally graded by class, with Class I fruits sold fresh, whilst class II fruits are normally processed and sold through farm shops or similar, alternatively, sold directly to processors.

Waiting bed plants are grown on from runners and planted into a 'waiting bed' at a low density to produce a large, healthy plant. Plants are runner cut and de-blossomed in order to maximise crown size, truss numbers and flower counts. These are then lifted when dormant and cold stored for spring or summer planting.

Tray raised plants are usually grown in a 50:50 peat and coir mix. Tray plants maximise the truss and flower number on each plant, allowing growers to effectively plan their planting and cropping cycles.

Misted tip plants are rooted cuttings taken from strong runner tips in early summer and grown on under glass in special modules; forming a strong multi-crowned plant. Transplanted plants develop quickly and initiate high quality flower trusses with the potential to deliver a full crop of Class 1 fruit. Yields in the first season are typically very high; as much as 1kg per plant can be achieved (double the average yield of other plants).

A+ runner plants are the preferred planting stock for greenhouse grown berries. Having a large crown diameter, A+ runners benefit from a greater numbers of flowers and higher yields.

2.4 Nutrition

Strawberries are fertilised from early signs of growth in spring, with concentrations of nutrients applied corresponding with crop developmental stages. An early feed in spring will have higher proportions of N to boost vegetative growth. As fruits start to swell, lower proportional N applications are introduced through to harvest. For everbearing varieties, which produce fruit over the 3 months August to October, the fruiting feed would continue throughout this period. Most nitrogen to potassium ratios suggested show an initial range between 1:1 to 1.2:1 (K:N), increasing to 1.7:1 to 2:1 (K:N) at fruiting[11].

Should the decision be made to overwinter the crop, rather than grown as a 60 day crop, the plants will require nitrogen and phosphate, following picking, to sustain crown production and also initiate flowers for the following year[10]. Feeding at this stage will be at a lower level, when compared to the main cultivation period, and will continue up until October.

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[12] Lieten P., Evenhuis B. and Baruzzi G. (2006). Cold Storage of Strawberry Plants. International Journal of Fruit Science, 5:1, 75-82.

Proprietary feeds are typically used in small operations, but greater flexibility and better optimisation of nutrients can be achieved through the in-house mixing of straight fertilisers. The HDC strawberry feed calculator[13] can help growers to calculate the quantities of fertilisers they need to use to make up their own nutrient feeds from straight fertilisers. If done correctly, this can maximise fruit quality and yield, whilst being more cost effective than proprietary formulations. It is common for nutrient stock solutions formulated from straight or proprietary fertilisers to be mixed at 100x the concentration of the feed being supplied to the plants. Fertiliser injector systems will dilute the feed with the irrigation water, before being distributed through the fertigation system.

Substrate Cation Exchange Capacity (CEC)

What is cation exchange capacity?

The sum of the exchangeable cations or bases that a medium can absorb per unit weight. This is expressed as milligram equivalents per 100 cm^3 (meq 100 cm^{-3}) because of the differences in the volume:weight ratios of the selected raw growing media materials. Media particles have negative charges on their surface, which can attract and adsorb cations from fertilizers such as Ca^{2+}, Mg^{2+} and K^+.

What effect does it have?

The cation exchange capacity (CEC) helps to regulate the supply of certain nutrients, such as Ca^{2+}, Mg^{2+}, K^+, NH^{4+} and Na^+. CEC also affects the regulation of pH. Growing media with a high CEC will recover more quickly from acidification compared with a media with a low CEC.

Low CEC: The medium doesn't hold on to cations in fertilizer added, resulting in nutrient deficiencies particularly in K^+ and Mg^{2+}.

High CEC: The media retains relatively large concentrations of cations and ideally makes them easily available to plants roots but prevents leaching when irrigated.

2.5 Irrigation Management

An adequate supply of water is essential to maximise fruit size, quality and yield. It is also important for water to be applied at the correct time, in sufficient quantities, but without excessive waste; even more so when nutrients are supplied through the irrigation system. Precision irrigation systems, such as drip emitters, avoid moisture related disease, especially botrytis, powdery mildew and black spot.

In substrate systems feeding is continual, with water and nutrients delivered by trickle irrigation lines or drippers. When crops are grown in soil-less substrates, the water available to plants at any one time is much less (because of restricted rooting volume), compared with a soil crop. Irrigation is therefore applied little and often throughout the day during periods of high transpiration and reduced on cooler dull days.

Irrigation averages 0.2-0.3 L per day per plant across the whole season, supplied in up to 10 applications per day, maintaining near full wetness throughout the production cycle. Irrigation peaks at 0.5 L per day per plant during the height of summer; with little to no irrigation applied in early spring[14]. This practice is controlled in some cases by moisture and electrical conductivity sensors in the substrate, but is often monitored and maintained manually by a member of staff. Monitoring of

[13] HDC Strawberry Feed Calculator. Available from: horticulture.ahdb.org.uk/strawberry-feed-calculator

[14] Atwood J. and Perry M. (2003). Irrigation best practise - A guide for soft and top fruit growers. ADAS report to Defra (horticulture and potatoes division).

feeds and substrate should be combined with foliar analysis to maintain adequate nutrition is delivered to the plants.

Excess irrigation is required to avoid the build-up of salts and maintain the E.C. in the root-zone. The amount of nutrients lost in drainage water is proportional to the irrigation strategy adopted by the grower. Typically, substrate grown strawberries are irrigated at 5-20% irrigation to waste, with an aim for zero drainage in the earliest part of the day. Growers are typically averaging 10-15% irrigation losses over a cropping season, naturally varying daily as the weather changes over the season. Reducing the irrigation to waste saves not only on water, but also fertiliser costs.

The drainage water tends to have a composition which is similar to the input feed but with a higher salt concentration, due to water withdrawal by the plant and the concentration of underutilised nutrients such as NaCl and sulphate (***Table 2***).

Table 2: *Nutrient balance sheet for strawberries in soil and substrate (values are per ha per cropping season ~180 days)*[8]

	SOIL	**SUBSTRATE**
Irrigation	0.2 L day per plant (averaged across whole season peaks to 0.5L/plant in high summer to almost nothing in early spring) supplied in several applications per day. Fertigation not continually supplied in irrigation water	0.2-0.3 L per day per plant (averaged across whole season peaks to 0.5L/plant in high summer to almost nothing in early spring) supplied in up to 10 applications per day. ~3,240m^3/ha/yr
Planting density	40-50,000 plants/ha	55-65,000 plants per ha
Nutrients supplied		
Nitrogen (total N)	60 kg/ha	200 - 300 kg/ha
Phosphorus (P2O5)	40 kg/ha	60-100 kg/ha
Potassium (K20)	100 kg/ha	200 - 330 kg/ha
Magnesium (MgO)	50 kg/ha	36 - 54 kg/ha
Irrigation to waste	5-10%	5 - 20%
Nutrients in runoff		
Nitrogen (total N)	6 kg/ha	4 - 40 kg/ha
Phosphorus (P2O5) *(elemental P)*	4 kg/ha *(1.8 kg/ha)*	4 - 13 kg/ha *(1.8 - 6 kg/ha)*
Potassium (K20) *(elemental K)*	8 kg/ha *(6.6 Kg/ha)*	4 - 43 kg/ha *(3.3 - 35.7 Kg/ha)*
Magnesium (MgO) *(elemental Mg)*	5 kg/ha *(3 kg/ha)*	1 - 7 kg/ha *(0.6 - 4.2 Kg/ha)*

2.6 Pollination

As soon as the first flowers open bees should be introduced to assist in pollination. Some varieties, such as Elsanta, can be affected by poor pollination, giving rise to high proportions of misshapen fruit.

Either bumble bees or honey bees can be used on early crops. Bumble bees are available from a number of biological control companies, such as Koppert UK, Syngenta Bioline or BCP. While more expensive than honey bees they are more active in cool dull weather, which often prevails early in the year, and are also less likely to become aggressive if temperatures are high. The hive is placed inside the growing house, whilst honey bees are best placed outside the structure with a covered entrance

to allow access to the crop. A stocking rate of 1 hive/1,000 m^2 is suggested and 4 per Ha of the bumble bee boxes.

2.7 Postharvest Handling

Unless the crop is being grown for PYO, after the crop has been picked, postharvest measures will be required to ensure crop quality up to the date in which they are marketed. The fruits should be taken from the field to the chiller in 30 minutes or less and cooled to 2^0C, then it is packaged into punnets or crates of suitable size for the intended market, and stored in a chilled pack house at 10 – 15°C.

Larger scale growers may have access to existing pack house chilling facilities, although smaller producers may wish to use commercial-size refrigerators or cooled trailers which can be hired during the season. If fruit is being harvested over a wide area mobile cooling units in the field may help to chill fruit before it reaches the pack house.

3 Market Information

3.1 Welsh Market Potential

Recent analysis of consumer purchasing habits amongst the large retailers indicates that as of 1st March 2015 the strawberry market in Wales is worth £24.9 million, with 5.4 million kg of strawberries being sold. The strawberry market has grown at a Compounded Annual Growth Rate (CAGR) of 1.5% in volume terms, and 3.8% in value terms; with much of the growth resulting from an increase in shopper frequency (rather than larger single purchases) and varietal development for premium produce markets[15].

Between 2010 and 2015 the amount of land used in Wales for orchards and small fruits has increased by 16%[16]; representing an overall share of 48% of all Welsh horticultural land currently in production. The area under glass or plastic cover in Wales has steadily fallen from 38ha to 29ha, despite continued expansion across the UK.

As with most agricultural production in Wales, from 2012 to 2014 horticultural holdings have been decreasing, and may partly explain the reduction of protected culture, however since 2015 we are seeing growers returning to the land, with horticultural and minor holdings production systems favoured.

The well distributed nature of smallholdings in Wales makes berry production, and especially selling into the local market, particularly lucrative. As the number of growers has been increasing, many of Wales' fresh produce distributors are also actively looking to improve their local offering and can provide efficient routes to market for some growers. Therefore, reducing associated risks with crop perishability resulting from receptiveness and ability for local markets to absorb produce at harvest time. The marketing of fresh produce through honesty boxes at the farm gate, Pick-Your-Own (PYO)

[15] Horticulture Wales (2015). Market Analysis: Retail Analysis of 10 Horticultural Crops. Available from: tinyurl.com/ychupzer

[16] Farming Connect (Business Wales, Welsh Government). Horticulture in Wales. Available from: businesswales.gov.wales/farmingconnect/posts/horticulture-wales

operations and vegetable box schemes have also proven popular; affording the grower healthy profits for lower volume production.

For growers producing larger volumes and who are interested in supplying the national supermarket chains, it is common to sell your produce through Producer Organisations (POs), such as Berry Gardens, BerryWorld UK and Fruition PO.

3.2 Market Overview

Per capita consumption levels in Wales and Great Britain both average 1.78 kg per person p.a., with consumers in Wales spending an average of £8.08 per kg per person p.a. on strawberries. Some opportunities may exist in the 'Family 10 years plus' group who are underrepresented by purchases in Wales, suggesting that there is further potential for growth[15].

Opportunities may exist to produce locally grown soft fruits for Pick-Your-Own, high end markets and retail outlets. Producers who grow locally are at a distinct advantage as less investment is required for storage facilities and transportation costs are reduced. Premium varieties which don't store well are also more viable option. For out-of-season production, when growers are more likely to be competing against producers in Southern Europe, Welsh growers can pick their berries at a riper stage, giving their berries a fuller flavour profile, due to shorter supply chains (strawberries produced in Southern Europe take on average two to four days to reach the UK).

Early season and end of season wholesale fruit prices tend to be the highest; with the largest price differential between class I and class II fruit seen when smaller volumes of class I fruit are being produced due to adverse weather conditions (***Fig. 3.5***). The use of protection not only allows for season extension, but increases the likelihood of achieving high class I yields when the highest returns on investment can be made.

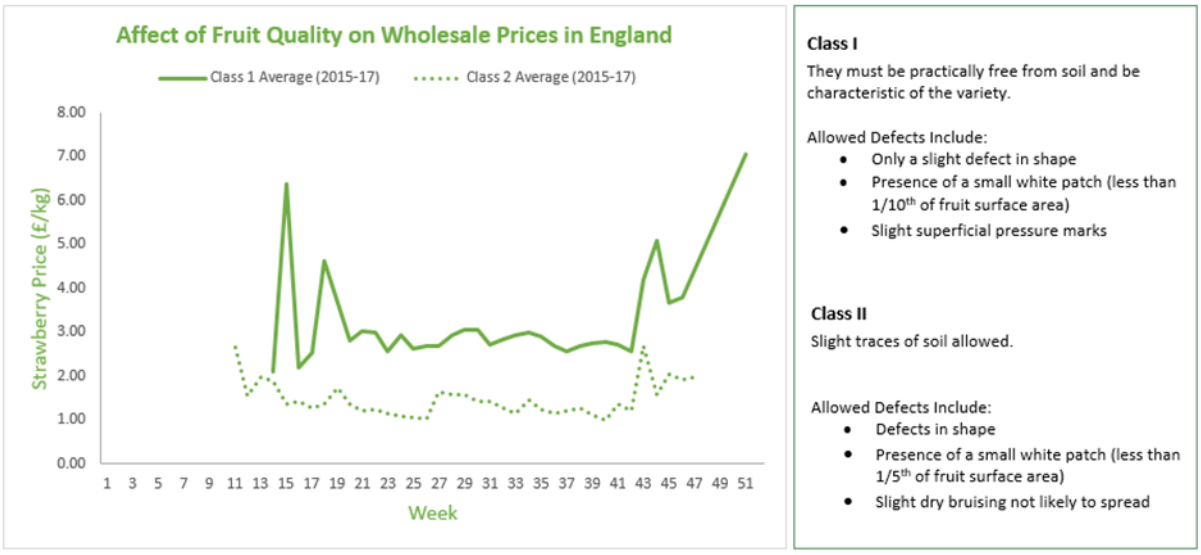

Fig. 3.5: *Correlation between fruit quality and wholesale market price[17].*

[17] Defra (2017). Wholesale Fruit and Vegetable Prices, Weekly Average. Raw data source: tinyurl.com/y78ll6d3

3.3 Varietal Selection

Continuous production is just one aspect of varietal choice; it is important to select cultivars suited to the specific challenges and specifications of the market you will be supplying. Some cultivars may have high yields, low input and high disease and pest resistance, but if they are a variety which isn't favoured by your intended market, there is little benefit in its cultivation.

Some cultivars will do better than others in particular systems and climates. For example plants which are too vigorous in protected environments, may achieve higher yields, but may result in lower BRIX numbers, from too vigorous uptake of water and nutrients. It is important to trial several cultivars in your system and climate to find what works best for you.

The main varieties grown in the UK are often proprietory, owned and grown by members of particular the POs only, with independent growers and PYO operators focusing on varieties free from legal protection, such as Malling Centenary, Elsanta, Sonata and Florence. PYO growers will often overwinter their crop by dropping tabletop bags to the floor by placing on top of black plastic topped with Mypex, to prevent frost damage. Grouping bags together will give extra warmth and reduce frost damage risks, with fleece used as extra protection during cold nights[18].

When everbearing varieties are grown for a second year or longer, you must take into consideration that the second years' picking period will coincide with that of June bearing varieties and it is advised that you plan accordingly. However, the practice of wintering a crop is not normally followed by supermarket growers due to the variability of fruiting and picking period; which is unconducive to supplying the large retailers.

4 Business Development

4.1 Investment Potential

The benefits of hydroponic production make it suitable for external support, particularly via rural development program grants administered through the Welsh Government. The current program, running until 2020, is aimed at enhancing the competitiveness of Welsh agriculture, ensuring sustainable and efficient management of resources, and promoting innovative farm technology. All of these themes are directly supported by hydroponic techniques, making grant support for the associated technology a realistic potential.

4.2 Production Site Location

Polytunnel planning permission considerations should focus upon mitigating against environmental damage and ensure continued public enjoyment of rural areas. Along with adhering to buffer zone restrictions for agrochemicals and correct orientation of tunnels to reduce wind run and maximise solar irradiance, excess waste nutrient solution must be correctly managed.

In table top systems excess irrigation water will drain to the soil below, if not intercepted, with weeds and grass in the alleyways assimilating some of the nutrients. Growth can be vigorous and the non-crop vegetation needs to be managed to restrict growth, and due to the additional management implications and cost many growers opt for bare earth beneath and between crops increasing the

[18] ADAS UK Ltd. (2016). Fruit Notes: Issue No. 37/16 (19 December 2016).

potential risk of nitrate and phosphorus pollution. The potential for water pollution from table top production sites are increased if located close to sensitive ecological sites, drinking water abstraction areas for surface water and Source Protection Zones (SPZ) for ground water[8].

Choosing the most level site possible is the most significant factor to reduce surface runoff to a watercourses and human habitation. Removal of roofs through winter also reduces the channelling of rainfall in the wettest months. Grassing or mulching alley ways and leg rows provides ground cover below table tops to sequester nutrients and pesticides as well as reducing surface runoff and soil disturbance. In addition, increasing the number and size of buffer strips and zones at the margins of polytunnel sites will improve the sites' capacity to assimilate pollutants. Attention needs to be directed towards correct buffer strip management for effective pollutant on-site sequestration[8]. Alternatively, collection, cleaning and fertigation with drainage wastes should be considered, as discussed in section 4.5 of this toolkit.

4.3 Main Season Production Calendar

Key activities carried out during a typical growing season for a characteristic main season strawberry crop were partitioned (***Table 3)***. Producers growing over different periods of the year may come across different challenges related to climate, as well as pest and disease pressures. However, it should be noted that polytunnel covers are normally removed at the end of the season to prevent wind shear damage, and refitted again at the start of the season.

Table 3: *Typical cropping calendar for main season strawberry production[8].*

December - February	March - May	June – August	September - November
Planting, winter herbicide applications residuals and contact. Nutrient analysis of substrates.	Polytunnels cladding. Spring fertigation 4-6 weeks through trickle irrigation. Late April early fruit ripening, fruiting fertigation started on early crops continues for 6 -16 weeks. Routine fungicides applied and insecticide as required. Planting will continue for late crops.	Harvest continues, fruiting fertigation. The application of fungicides and insecticides as required, IPM strategy generally practiced.	Tunnel cladding removed post-harvest. Fertigation continues into early October at a reduced rate. Contact and residual herbicides applied.

4.4 Clean Plant Material

In England and Wales, the Fruit Propagation Certification Scheme (FPCS) encourages the production and use of healthy planting stock, with the Nuclear Stock Association (NSA) administering the service, under the authority of FERA Plant Health and Seeds Inspectors (PHSI). It is advised to purchase plant material only from propagators using certified plant material, whether they are propagated in the UK or abroad. It is advised that growers have samples tested for common strawberry diseases, specifically those most prevalent in table top systems, at their local plant clinic prior to confirmation of their purchase.

4.5 Reuse of Irrigation Water

Recycling of waste nutrient solution to the same crop presents a very real risk of *Phytophthora* spp. and other root borne pathogens causing hefty losses to strawberry crops.

Some table top production sites are collecting irrigation waste using gutters under the bags or troughs. There is potential to reuse waste irrigation water on other soft fruit crops (e.g. waste water from strawberries going to raspberries as the diseases are host specific) providing a water and fertiliser saving. This option will be of particular interest to PYO or other diversified growers looking to make the most efficient use of their resources. However, excess solution can also be directed to broad acre crops or grassland to utilise the waste nutrients according to existing waste disposal guidelines (CoGAP).

4.6 Pest & Diseases

4.6.1 Disease Control

Of primary importance for the grower is to purchase plant material free from pathogens, and to ensure proper cleaning of implements during cropping to limit the spread of any pathogens that may exist. These may originate from the lifting of plants from the field during the propagation stage, as in the case of red core; or may originate from infection of fungal spores during cold storage (i.e. crown rot).

Varietal selection can greatly affect a plants' susceptibility to different diseases; where possible, tolerant or resistant varieties should be used. Proper planning can help limit operational costs and over reliance upon fungicides; particularly under the hot dry conditions of late summer for powdery mildew, or humid conditions and temperatures around 20^{o}C for botrytis. Actively reducing relative humidity and increasing temperatures creates an environment which is unconducive to botrytis spore development and germination.

4.6.2 Pest Control

Pest control is increasingly being managed through introductions of biological control agents such as predatory insects. This represents a significant labour increase for their application but is required as certain insects are now resistant to all available insecticides and there is increasing pressure from retailers for pesticide residue reduction.

Pests and certain diseases, such as powdery mildew, are more prevalent in a tunnelled environment, so polytunnels need careful venting (adding a significant labour cost) to avoid a build-up of excess humidity and extremes of temperature. Everbearers are also increasingly being grown as annual crops because of carry over problems with Western Flower Thrips.

5 Table Top Strawberry Production – A Case Study

Prices tend to rise as tunnel production reduces in the autumn and again in spring, when prices reduce as the tunnels begin to crop. The UK crop generally has a premium over cheap early produce, often imported from Spain or North Africa. Strawberry production in glasshouses is ideally scheduled to avoid the main crop production season in Spanish tunnels, which is commonly picked in May with some volume, and continuing on until October.

Glasshouse crop production will aim for October, with the crop chilled and overwintered; to crop in March and April (***Fig. 5.2***). Availability of glasshouses are likely in former salad growing areas, for example in Lancashire and Vale of Evesham. With little competition from tomato growers, who require glass of a higher specification for production, strawberry growers therefore may have a selection of glasshouses available to them, either to buy or rent.

In this case study, out-of-season greenhouse production is followed, with increased demand established through the creation of strong branding, with sustained sales achieved through the main season due to a strong brand image. A large proportion of the crop (Malling Centenary [**Fig. 5.1**], a popular, good quality tasty fruit, which attracts a premium price) being sold into a locally based supermarket.

Fig. 5.1: *Typical quality punnetted Malling Centenary produced in the greenhouse system in this case study.*

Fig. 5.2: *Tray plants shortly after planting, note use of reflective white polythene.*

Frigo Malling Centenary tray plants are purchased annually and are planted out in substrate bags, using the artificial media fyto-cell. The plants tend to produce fruit about 60 days from planting (usually established in July and August) and will crop for 4 weeks, although this will extend as the autumn days shorten and temperatures fall away. Picking is done daily and any substandard fruits sold to local farm shops, but with Malling Centenary this is usually under 10%. Tray plants are transplanted at a cropping density of 10 plants per metre of bags, and a premium price of £5.00/kg is achieved.

6 Next Steps

The decision to develop a hydroponics venture must be based on a strong analysis of the potential market for strawberries, both through existing market routes and the potential to access new customers. This will enable identification of likely product types and methods of production to be identified, which in turn will assist in the development of a financial feasibility study into the launching of a new hydroponics product line.

For growers inexperienced in strawberry production, discussion with independent advisors will be essential in identifying the best methods of exploiting hydroponic techniques, along with advice regarding crop management, agronomy and marketing to maximise the possible benefits of the new hydroponic venture. The unique nature of hydroponic growing will be its unique combination of potential challenges, and seeking advice will minimise the impact of these on new start-up ventures.

This section contains a list of suppliers, which are not exhaustive, nor should the list be considered as a recommendation over other suppliers in the market.

SUPPLIERS OF PLANT MATERIAL

Aardbei Extra
Belversestraat 5
5076 PV Haaren
The Netherlands
Tel. +31 (0)411 62 1693
www.aardbei-extra.nl

Beeren Plant Products
Brumholt 5a
6086 PV Neer
The Netherlands
Tel. +31 (0)475 49 2658
www.beeren-plantproducts.com

Berry Plants Ltd
Wills Farm Buildings
Wills Lane
Newchurch
Romney Marsh
Kent TN29 0DT
Tel. (01303) 872 444
www.berryplantsltd.co.uk

De Kemp BV
Kempweg 15
5964 ND Horst – Meterik
The Netherlands
Tel. +31 (0)773 98 2430
www.dekemp.nl/en

EU Plants Ltd
Millets Farm
Garford
Abingdon
Oxfordshire
OX13 5PD
Tel. (01865) 392 863
www.euplants.com

Fragaria Holland
Galderseweg 83
4855 AG Galder
The Netherlands
Tel. +31 (0)765 61 2227
www.fragariaholland.nl

Genson Soft Fruit Plants
Rijtvenweg 8A
5491 PJ Sint-Oedenrode
The Netherlands
Tel. +31 (0)413 20 9254
www.genson.nl

Hargreaves Plants Ltd
Church Farm
Station Road
Hillington, Kings Lynn
Norfolk
PE31 6DH
Tel. (01485) 609 252
www.hargreavesplants.com

R W Walpole Ltd
Ivy Farm
Terrington St Clement
King's Lynn
Norfolk
PE34 4PX
Tel. (01553) 828 829
www.rwwalpole.co.uk

Vissers Aardbeiplanten B.V.
Midden Peelweg 10
5966 RE America
Limburg
The Netherlands
Tel. +31 (0)774 64 8100
www.vissers.com

Welsh Fruit Stocks
Bryngwyn
Kington
Powys
HR5 3QN
Tel. (01497) 851 209
www.welshfruitstocks.co.uk

SUPPLIERS OF SOLUBLE FERTILISERS

ICL
Boulby Mine
Loftus
Saltburn-by-the-Sea,
Cleveland
TS13 4UZ
Tel. (01287) 640 140
www.icl-uk.uk

Solufeed Ltd
Highground Orchards Office
Highground Lane
Barnham (Nr.Bognor Regis)
West Sussex
PO22 0BT
Tel. (01243) 554 090
uk.solufeed.com

Yara UK Ltd
Harvest House
Europarc
Grimsby
N E Lincolnshire
DN37 9TZ
Tel. (01472) 889 250
www.yara.co.uk

SUPPLIERS OF SUBSTRATES

Bord na Mona
Main Street,
Newbridge,

Bulrush Horticulture Ltd
Newferry Road
Bellaghy

ICL
Boulby Mine
Loftus

Co.Kildare
W12 XR59
Ireland
Tel. +353 45 439000
www.bordnamona.ie

Magherafelt
County Londonderry
BT45 8ND
Tel. (0287) 938 6555
www.bulrush.co.uk

Saltburn-by-the-Sea,
Cleveland
TS13 4UZ
Tel. (01287) 640 140
www.icl-uk.uk

Sinclair Pro
Bridges Road
Ellesmere Port
Cheshire
CH65 4LB
Tel. (0151) 356 6014
www.sinclairpro.com

EQUIPMENT SUPPLIERS

(F): FERTIGATION, (T): TABLETOPS, (P): POLYTUNNELS, (C): CONSUMABLES

Elite Tunnels Ltd
The Office
Arnhall Farm
Edzell
Brechin. DD9 7UZ
Scotland
Tel. (01356) 648 598
www.elitetunnels.com
(T), (P), (C)

Haygrove
Redbank
Ledbury
Herefordshire
HR8 2JL
Tel. (01531) 633 659
www.haygrove.com
(T),(P)

Hortech Solutions
Thingehill Court
Withington
Hereford
HR1 3QG
Tel. (01432) 850 692
www.hortechsolutions.co.uk
(F), (P)

JB Hydroponics BV
Honderdland 170
2676 LT Maasdijk
The Netherlands
Tel. +31 (0)174 29 2662
www.jbhydroponics.com
(T)

LS systems
184 Blackgate Lane
Tarleton
Preston. PR4 6UU
Tel. (01772) 812 484
www.lssystems.co.uk
(C)

Meteor Systems
Minervum 7081
4817 ZK Breda
The Netherlands
Tel. +31 (0)765 04 2842
www.meteorsystems.nl/en
(F), (T)

Northern Polytunnels
Mill Green
Waterside Road
Colne
Lancashire. BB8 0TA
Tel. (01282) 873 120
www.northernpolytunnels.co.uk
(F), (P), (C)

Priva UK Ltd
34 Clarendon Road
Watford
WD17 1JJ
Tel. (01923) 813 480
www.priva.com/uk
(F)

Pro Tech Marketing
Severn View
Buildwas Road
Ironbridge
Telford. TF8 7BN
Tel. (01952) 433 123
www.pro-tech-marketing.co.uk
(T), (P)

Wroot Water Ltd
Thatch Carr Farm
Field Lane
Wroot, Doncaster. DN9 2BL
Tel. (01302) 771 881
www.wrootwater.com
(F)