Soilless Cultivation

For Leafy Salads

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

The production of crops without soil, typically through hydroponics, using nutrient-enriched solutions with or without growing media, offers a unique opportunity for the Welsh horticulture sector. These systems are particularly beneficial when producing leafy crops such as leafy salads which can be grown at high densities and achieve higher marketable yields compared with similar crops grown in soil. The market has diversified, with consumers seeking a varied diet of multi-leaf salad mixes including micro-leaf lettuce, watercress and pea shoots. Mixes including coloured leaves such as amaranth and chard, or flavourings including baby celery leaf and herbs, are in particular demand in the food service industry. The UK prepared leaf salad market grew by 6.6% in 2017 to almost £700 million[2] buoyed by continuing consumer demand for fresh, nutritious produce that aligns with emerging "superfood" trends. Seasonal demand peaks in the summer, but continued demand from restaurants throughout the year can ensure a market for as long as the salad can be grown.

Welsh locally grown leafy salads present an excellent product development opportunity for horticulture: it is a short growth cycle, high value product which shows rapid drops in flavour and quality in extended supply chains. By increasing the availability of locally-grown, high quality salads, growers will be able to exploit the increasing consumer demand and increase the profitability of their growing enterprise. Salads also align with the long-term vision of the Welsh Government for horticulture, by diversification from traditional horticulture soil grown crops. New leafy salad crop selections, which are well suited to soilless growing systems will add value to a regional supply chain – Welsh-grown salads would offer sound investment potential for Welsh-made food and drink products, marketed directly to consumers.

Leafy salads are well suited to hydroponics and can be developed as a new business or an extension of an existing business. Salads can be grown in a range of glasshouse or polytunnel structures. Salad leaf crops can be grown at high densities with shorter growing times, achieving 3 – 4.5 kg/m^2 compared with yields of 2.5 – 3 kg/m^2 for field grown lettuce. This approach also minimises pest/disease risk, such as *Pythium* which can persist in the soil between crop rotation. Weed control is also much easier as there is little space in the production system for weeds; weed control can be particularly problematic for herbicide-sensitive rocket, when grown in the field. As salad is eaten raw, the ability to grow a crop in the absence of soil minimises the risk of contamination enhancing marketability of a clean crop. High planting densities also increase the efficacy of biological controls for pests and disease management in the root and shoot zones.

Labour costs can be reduced by stacked or table-height production compared with crops grown in the ground in a single layer. The ability to control the growing environment means that optimum resource efficiency can be achieved while offering a highly uniform and consistent product that has the potential to be grown year-round. The recirculation of water and nutrients means that water wastage is 20 times less than that typically seen in soil grown systems, which is an important environmental protection measure for sustainable food production. While soilless cultivation methods can be started at a relatively small scale using basic technology, it can be readily integrated with innovative growing technology such as light-emitting diode (LED) lighting to greatly increase output and production efficiency from the growing area.

This document has been written as a practical guide for growers who are seeking to diversify their business using hydroponic techniques.

[2] Fresh Produce Journal, 27/09/17

2 Hydroponic Growing

Growing plants without soil is a precise method to deliver water and nutrients to match crop demand; because of the enhanced availability of resource to the root-zone, crops can be grown at a higher density than would be possible in the field. It also allows tight control of the growing conditions so that optimum quality produce can be grown, and the absence of soil means that a cleaner crop can be harvested which is of benefit for salads which are eaten raw. Optimum water and nutrient access also improves rates of growth, and because soil-borne diseases are avoidable continuous production from the same space is possible.

A core feature of any hydroponics system is the use of a carefully controlled nutrient solution to provide water and key nutrients to the crop (**Fig. 1** and **Fig. 2**). This can be applied to the bare roots in substrate-free systems (such as in the nutrient film technique or NFT; **Fig. 3**) or applied to plants supported by an inert substrate. The nutrient solution is maintained as a recirculating stock which is collected after application to the crop, ensuring high efficiency of resource use and minimising the environmental impact of nutrient run-off. While this can be prepared using pre-formulated mixes, it can be tightly controlled to provide an optimum, uniform growing environment for the crop. Two key features of the nutrient solution that will require control are pH and electrical conductivity (see key terms below).

Fig. 1: Bare root systems bathe the rootball directly in a nutrient solution ensuring optimum application.

Key Terms – Nutrient Solutions
pH – This is a measure of the acidity (below pH 7) or alkalinity (above pH 7) of the solution. This can have an impact on the availability of certain nutrients if the pH is too far from optimum, although this can be highly crop specific.
EC – Electrical conductivity (EC) is a measure of the proportion of ions dissolved in the solution. Nutrients dissociate into positive (e.g. K^+, NH_4^+) or negative (NO3-, PO_4^-) ions. As these conduct electricity, solutions with more nutrients dissolved give a higher EC (normally measured at µS cm-1 (microSiemens per cm). High EC can lead to plant damaged through toxic nutrient concentrations or difficulties absorbing water, or low EC can lead to stunting and other nutrient deficiency symptoms. EC changes with base water input, and should be regularly monitored.

Fig. 2: Cos lettuce grown in bench-style bare root systems. Plants can be grown at various densities to achieve required leaf sizes and maturation rates to meet customer requirements while allowing a range of crops to be grown in a single system.

Substrate-Free Hydroponics

Salad leaf can be grown almost completely without substrate, supported only by a small plug in which the plants were originally germinated. This system is particularly suited to short life-cycle salads, such as those being grown for a single cut harvest e.g. pea shoots. The basis of these systems are that the roots of the crop are directly bathed in a nutrient solution, achieving optimum access to nutrients and water. Growing without substrates reduces costs, and can easily be used in passive (still solution such as Deep Water Culture [DWC]) or active (pumped or aerated solution) hydroponics, the most typical of which is the Nutrient Film Technique (NFT).

Nutrient Film Technique

In NFT systems (**Fig. 3 & Fig. 4**), plants are propagated into small rockwool blocks (3" or smaller), which are placed into an NFT irrigation channel supported by plastic caging. This can be achieved by using channels created by folds of plastic secured to create a channel with a flat base, or shallow PVC troughs up to around 5 cm depth, 10cm wide and up to 10m long at a 1 – 3% slope. Nutrient solution is pumped in at one end at a rate of around 1L/minute, flowing past the bare roots growing out of the rockwool before collection at the opposite end and storage in a master tank prior to recirculation. The growing slips typically include covers that can be closed flush with growing plants to keep nutrient channels in darkness to avoid algae growth. The channels should also have grooves running parallel with the channel to streamline the nutrient flow and prevent it from pooling underneath the roots. The system should be designed so that the slope (and therefore the flow rate) can be adjusted to best suit the requirements of the crop as this changes with maturity and season. Nutrient application is normally sufficient for troughs up to 15m, but lengths longer than this will require a second feed line to prevent nutrient deficiencies in plants at the far end of the trough.

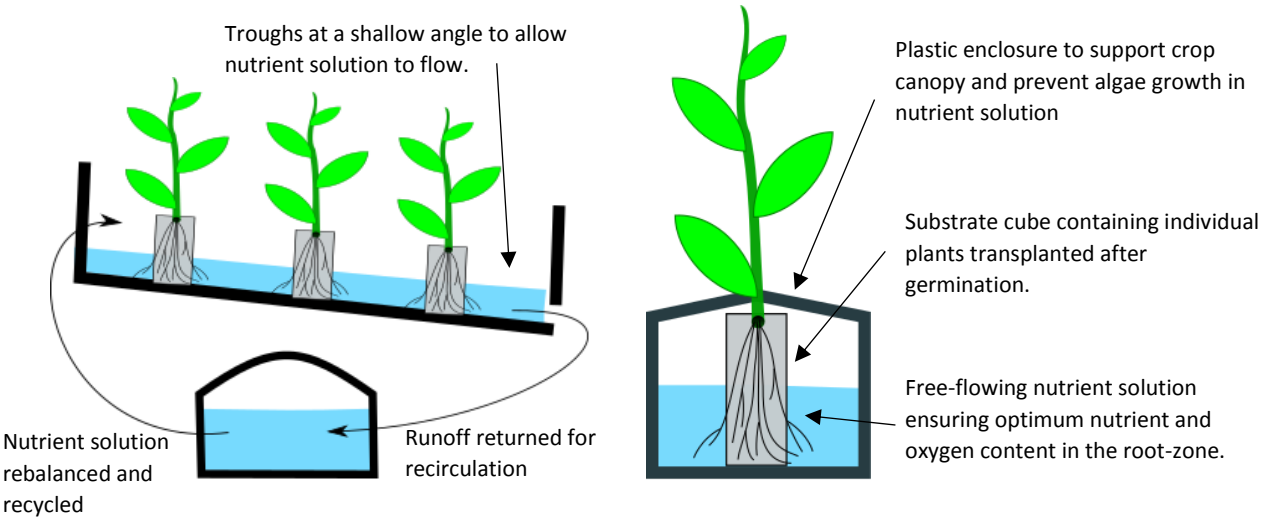


Fig. 3: Recirculated substrate-less hydroponic systems, Nutrient Film Technique (NFT)

Constantly recirculating nutrient solution ensures each individual plant is well supplied with water and nutrients, and the continuous flow ensures good aeration of the roots. However, root diseases may easily spread and the system needs to be monitored as there is little buffering of nutrients and water in the growing environment if problems should occur and the plants will be sensitive to any shortages caused by a disrupted flow should there be a power or pump failure. Exposed roots also means that they are less insulated from temperatures changes, but this can be mitigated by controlling the temperature of the nutrient solution, keeping it above 20°C.

Fig. 4: NFT Production of Lettuce: Individual lettuce plants are germinated in rockwool blocks before being grown in individual plastic cages (left). These are placed in the top of troughs into which nutrient solution is fed from a feedline from the master tank before flowing down the trough under gravity prior to draining and storage for later recirculation (right).

Deep Water Culture

In Deep Water Culture (**Fig. 5**) the bare roots of each plant are placed in a static nutrient solution of a greater depth than that seen in NFT, up to 10 – 25cm. Plants can either be held in channels above the solution in clay granules, or floated on the surface on expanded plastic rafts (e.g. styrofoam). This system is simpler as it does not require a recirculating feed or a separate master tank, and avoids the risk of technical failure depriving the roots of water and nutrients and can be established relatively quickly and cheaply. This system is particularly suited for leafy salads which show rapid growth when well hydrated, although this is typically used for large salads which require longer growing times such as whole head lettuce rather than baby or microleaf.

Achieving sufficient aeration of the roots can be difficult, and stagnant water can increase the risk of root-borne diseases such as *Pythium*. To minimise this risk, air must be continually pumped through the tank to promote water movement and provide oxygen to the roots. This can be achieved by pumping air from air stones or soaker hose to a constant fine stream of bubbles through the nutrient solution which can make contact with roots. Alternatively, surface agitation and mixing caused by falling water (e.g. from a pipe opening above the tank) can be useful in large systems, and while this will require pumping equipment there is reduced requirements for aeration as this can be done only in the master tank rather than each growing pool. Such systems act like ebb and flood hydroponics (see below) except that the plants are continually submerged and have only minimal substrate support.

Pre-formulated nutrient mixes can be used, although more experienced growers may wish to adjust these to optimise applications to their crop. DWC systems typically can be more dilute at a lower EC than NFT systems. Nutrient solutions will last around 21 days before replacement, but this will vary depending on crop type and growing stage, although this can be extended by topping up the nutrient solution with a diluted master mix if the EC and pH is within expected ranges. The pH will need to be kept within typical ranges, but a lower EC may be required especially when plants are young. Any large swings in pH and EC are to be avoided, and may indicate that the nutrient solution requires

replacement. Working with a more dilute nutrient solution lowers the buffering effect of pre-formulated solutions, risking larger changes in pH in older solutions. In these systems, oxygen concentration may require monitoring and commercial systems are available for this. Temperature may also require monitoring – dissolved oxygen content will fall at temperatures above 21°C, while temperatures below 16°C risk slowing growth rates

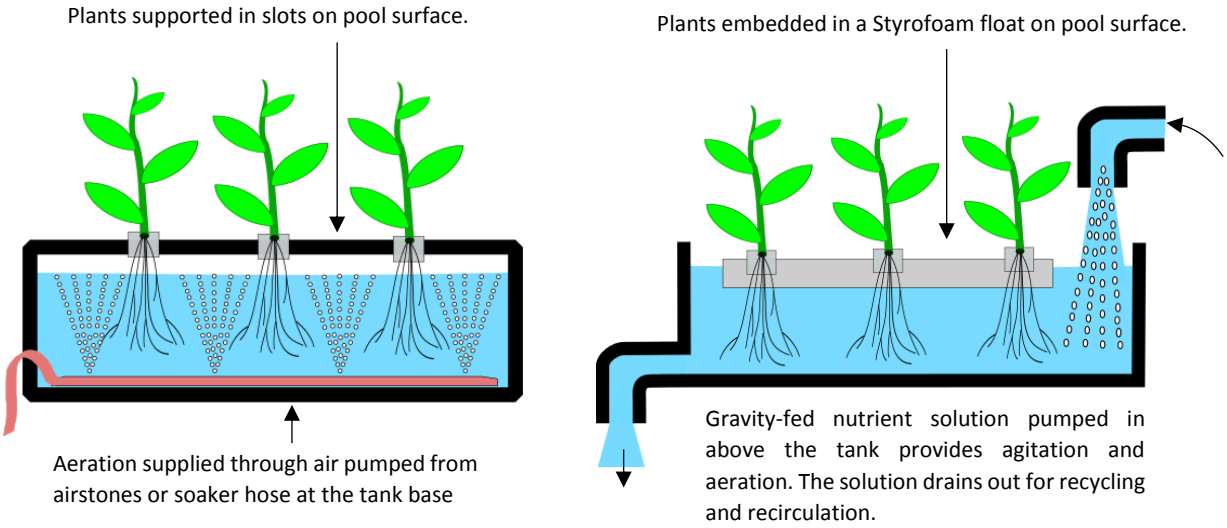


Fig. 5: Deep Water Culture of Lettuce: Butterhead lettuce grown on styrofoam rafts floated on nutrient solution grown under plastic. A wide range of varieties can be grown at once, with different ages of plants being grown in batches to meet customer demand (right). Free floating in deep water culture allows a more extensive root system to develop ensuring optimum supplies of water and nutrients as the plants mature (left).

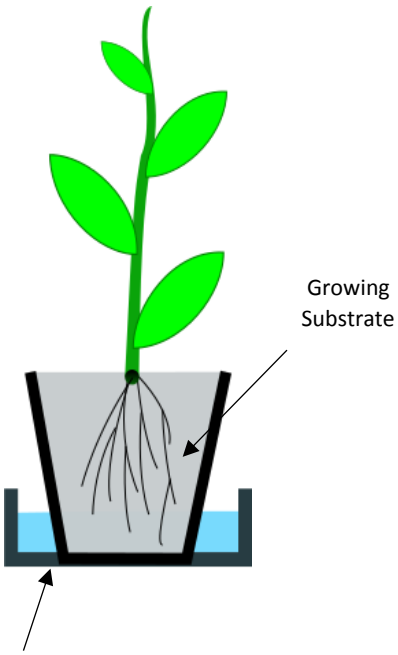
Substrate-grown Salad Leaves

An alternative to substrate-less cultivation, salads in substrates can also be grown hydroponically. While this is not a typical approach it allows leafy salads to be grown without dedicated DWC or NFT equipment. This is most suitable for salads to be grown as microleaf potted into shallow trays containing media where high densities can be used to shorten harvest times and limit leaf development keeping leaves within narrow specifications. This can also be used for uncut microgreens which are grown on to substrate mats which are sold to the consumer as a single unit, helping to preserve product quality by harvesting the leaves immediately before use.

The use of a substrate means that the roots are less exposed to disease risk from high volumes of recirculating nutrient solution, and the substrate can act as a buffer to changes in pH or EC. Substrates also offer excellent aeration, allowing optimum uptake of nutrients. Substrates will need to be replaced, but this additional cost can be mitigated by recycling of organic substrates. A range of substrates are available (see below) and choice can be made on the basis of end product or existing infrastructure: for instance, growers that already having potting up equipment can easily use organic substrates for tray-grown salad leaves.

Ebb and Flood

Ebb and flood systems (**Fig. 6**) are a common form of substrate-based hydroponics due their simplicity and flexibility, and can be adapted to suit a variety of settings and scales. In its most basic form, the system consists of shallow trays or benches in which the plants grown in plastic trays are placed which is periodically flooded with nutrient solution pumped in from a central master tank. Once flooded, the nutrient solution is then allowed to drain off under gravity, returning to the master tank for recirculation. The substrate remains at optimum water and nutrient content as this is replenished with each ebb and flood cycle, and the timings of application (both the frequency and duration of the inundation) can be tightly controlled. This system can be applied to a broad range of container-grown salads with compatible feed requirements being the only limitation. Another problem with the system is that algae can accumulate on the growing trays and will need to be cleaned out, but much less grows on the finished product due to bottom-up watering, a concern with other systems.



Frequent ebb and flood of the root-zone with nutrient solution.

Fig. 6: Sub-irrigated hydroponic system

When using substrates, it is essential that this is allowed to drain freely and that runoff nutrient solution is captured and recirculated. This ensures sufficient aeration of the roots, and efficient reuse of the water. Any system should be designed to ensure the free-flow of the nutrient solution after application. The frequency of nutrient application is heavily reliant on the crop and system used, but grower experience of crop requirements will also play a key role in determining irrigation guidelines.

Types of Substrate	
Peat	Peat has historically been the basis substrate for growing, but its use has been declining due to sustainability concerns. It offers excellent water and nutrient retention, although it is not inert and can carry a low pH. This remains a suitable substrate for pot-grown herbs.
Peat free (Blended raw materials)	Peat-free mixes can be variable across different points in the season and using peat as a base avoids this problem. Typically growers will use a blended substrate mix, including a variety of components to achieve optimum water and nutrient balance. This can be based on a blend of peat, coir, green manure, woodfibre, bark and perlite. Such mixes can be purchased pre-blended to meet a range of crop requirements. The industry standard is now a 25% reduction in peat, often with bark or woodfibre, with reduced peat options substituting roughly half of the peat with aforementioned alternatives.
Peat Free (Coir only)	Produced from the waste husks of coconuts, coir is a common substrate for hydroponics. It offers better nutrient retention and buffer than rock wool and offers excellent aeration. It is relatively inert meaning that tight control of nutrients can be maintained, and is both sustainable and recyclable. This is available in prepared slabs of varying composition and typically blended with other components such as woodchips. Coir is best used for drip-fed irrigation, and is suitable for longer-grown crops such as roses grown for the cut-flower market.
Rockwool	Rockwool is a fully inert medium made by heating basalt rocks. It is available in slabs of a range of sizes, including propagation plugs, and in a granulated form. It has good aeration, and can be used with drip irrigation. It is excellent for propagation, but has little buffering action and can be prone to overwatering so can be tricky to use in the long term, but can be used to give high-yields in multiple cut systems if used correctly. It can't be recycled or composted, but can be used directly off-the-shelf.
Grow Felts	Also known as substrate mats, most notably used in this instance for the clean and efficient production of microleaves, allowing leaves to be harvested immediately before use.

Propagation

Typically, propagation will be carried out in-house on a continuous basis to ensure continuity of supply and to keep costs down. Seeds in a raw or pelleted form are available for bulk-purchase from a range of suppliers. Seed can be sown directly into propagation blocks (typically rockwool, or other substrates can be used if they can be sterilised before use) before germination at 25°C, with low lighting. Nutrient solution at a lower concentration (typically around 50% of that used for normal growing) can be used during the propagation stage. New plants should only be transferred to the main hydroponic system once sufficient root growth outside of the propagation blocks can be seen – this is particularly important in NFT systems to ensure the young plants have sufficient access to water and nutrients. Short sowing-to-harvest periods (which can be as little as 5 – 10 days for microleaf salads) can be used to timetable new sowing of seed to match anticipated customer demand and ensure a regular supply of mature plants are available for harvest.

Crop Management

Leafy salad crops, particularly lettuce, can benefit from a slightly cooler temperature during maturation. Higher temperatures, or other stress factors including dryness, high EC or root damage can trigger bolting, particularly in plants grown at high densities for babyleaf. Bolting, or the formation of flower stalks, can lead to a bitter flavour in the crop, lowering quality. This can be avoided by careful crop management and cultivar choice. Some salad varieties (e.g. rocket or sorrel) should have a stronger taste, and this can be managed through nutrient/EC management.

Another quality trait linked to crop management is colour: leaves with a dark, vibrant red colour are desirable by consumers, and this requires high light levels in cool conditions to show strong

development. Faster growth in warmer conditions will dilute the red pigments in the leaves, weakening the colour but this can be managed by suitable control of nutrients and EC.

Regular routine monitoring will be required to match control of the nutrient solution to the crop's need and environment, and it is best practice to monitor both master tank and runoff to gain an understanding of how the crop is interacting with the system. For example, water uptake is likely to outpace nutrient uptake, increasing EC in hot, bright conditions. More established crops will require longer, more frequent flow cycles in ebb and flood systems so that crop demand can be better matched with supply. EC, nutrient application and pH will depend on a number of factors including the crop grown, target growth stages for harvest, season, maturation and system used. Source water must also be assessed so that the nutrient solution can be adjusted to achieve optimum concentrations. Growers in hard water areas may need to acidify the water before adding nutrient mixes, and will be running at a higher EC than growers in soft water areas. Under warm, humid conditions or if substrate-based systems are allowed to dry out, calcium transport in the plant can slow as transpiration rates decrease, rendering the crop at risk from tip burn. Avoiding temperatures above 25°C and ensuring good air circulation can minimise this risk.

All-year-round production will be possible if supplementary lighting can be provided, although this will carry additional costs and is likely to only be viable if high value produce can be marketed to a guaranteed customer (e.g. retail, restaurants).

Pest and Disease Control

Regular monitoring of pest and disease incidence must be carried out to avoid yield loss. Control of aphids, whitefly and mites must be planned as part of a targeted Integrated Pest Management (IPM) program. Good airflow is also essential to limit development of diseases such as *Botrytis* and powdery mildew. Typical pest control measures (e.g. yellow stick traps for the monitoring and control of aphids and whitefly) can be easily adapted for use in hydroponic growing systems.

Harvest and Sale

Whole-head salads (e.g. iceberg or cos lettuce) can be picked and plastic wrapped when mature, and may have a shelf life of around 1 week. Loose leaf salads can be packed into sealed bags or packet crates. Microgreens grown on absorptive media can be sold whole into food service outlets that can be cut as and when required.

Postharvest Handling

Once the crop is harvested, a measure of postharvest handling will be required. Cut salad levels should be washed, dried and stored in field crates before hand-mixing and then packaging according to customer requirements. For general consumer purchase, this may be packages in the range of 100 – 250g; but food service clients will require larger volumes of salad leaf in plastic or styrofoam crates.

Salad leaves should be stored at 10 – 15°C, in a humid environment to prevent drying out during storage. 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.

3 Market Information

The UK salad market continues to see strong growth. Lettuce achieved a market share of £206m in 2017, showing 8.1%[3] growth, buoyed by shortages leading to minor price inflation, although the market is still smaller than 15 years ago. The market demand has remained strong due to continued consumer interest in novel products, particularly flavoured salads including herbs or strong-tasting baby leaves. These can be sold for use as a base ingredient or as a garnish, but freshness and quality is key in achieving a high market value.

The breadth of variation in potential salad products means that salad leaf can be grown as a stand-alone product type, or integrated into existing mixed produce channels as an additional product line. This is particularly relevant to the foodservice sector, in which high volumes of fresh produce are required which benefit from localised production in a range of ways:

- Local production with short supply chains leading to short "field-to-fork" times. By keeping the interval between harvest and consumption as short as possible, the freshness of salad leaf in terms of quality and condition can be maximised.
- Consuming salad products close to harvest has been shown to preserve freshness, retain nutrition and to minimise the risk of food-borne pathogens growing after harvest. This also means produce can be sold in peak condition which is of importance for microleaf garnishes.
- Minimised carbon footprints, and food of a known origin marketed on the basis of locality. "Welshness" offers a strong marketing point, particularly with local consumers looking for healthy food products, sourced sustainably.

Product Choice

A wide range of salad leaf vegetables can be grown hydroponically, and while lettuce remains ahead in-terms of market share, much greater value can be achieved by growing more specialist cultivars, including microleaf salads (early leaves picked from immature plants) and oriental greens. While niche cultivars may require a greater level of management to achieve required levels of flavour, colour or quality, their value sets them apart from basic lettuce. Most cultivars have similar growing needs and so can be grown in combinations to suit customer requirements, and this even covers leafy herbs such as basil and coriander which can be included in flavoured mixed salads. Lettuce can be grown for loose-leaf, which allows multiple harvests and a variety of leaves to be grown together to give any number of mixed-leaf recipes. Besides lettuce, baby spinach and watercress can be suitable for bulk production, along with a range of more niche products as outlined below. Ultimately, product choice must be made on the basis of what local markets demand. If trading relationships with local foodservice stakeholders (restaurants, hotels etc.) are established engaging the customer in the decision making process will enable more informed decisions to be made about what products can be grown.

While the market is dominated by iceberg, this remains a low value, high volume product best suited for field-scale production. As an alternative, higher values can be achieved from more modern varieties which are seeing increasing demand by consumers looking to diversify their 5-a-day. Whole-head lettuce including Cos and Romaine (available in green and red leaf) can be grown well in DWC systems. More textured specialties such as Lollo Rosso, Frisee Butterhead and Oak Leaf can be grown for cut salads, but are best grown as part of a range of cut leaf to contribute to a mixed salad product.

[3] http://www.fruitnet.com/fpj/article/172955/fpj-big-50-products-2017-16-20, accessed 15/11/2017

In a similar way, spinach, rocket and watercress can be grown as independent products but are best marketed as a mixed salad with other varieties. Gourmet mixes can be developed from a wide range of cultivars, focusing on particular flavour or colour combinations.

Cultivar Choices	
Chard	Grown for tender leaves on brightly coloured petioles, chard is grown to be eaten fresh or cooked. This can be grown for multiple harvests from a single crop, increasing harvest windows.
Mizuna	Japanese leafy salad growing a finely divided leaves from a rosette with a mild peppery flavour for use as a garnish or flavouring in mixed salads.
Rocket	Longer leafed salad veg with a sweet, peppery flavour that can be sold on its own or used as a base for a mixed salad.
Watercress	High-value salad that can be sold individually or as a base for mixed salads. This benefits from cooler conditions, and grows well alongside lettuce.
Amaranth	Typically grown for microleaves, amaranth has shorter, more rounded leaves that can be grown to have very strong red colours that are sold to be freshly cut and served as a garnish. Red and green versions can be grown for larger salad leaves with a flavour similar to spinach.
Kale	A longer lived product, kale can be typically grown in substrate-based hydroponics and can produce multiple harvests from a single planting. This can be grown in a range of conditions, making it compatible with a range of herbs and salads. Smaller, immature leaves can also be used as salad leaf.
Herbs	Many herb cultivars such as basil and coriander grow very well in hydroponic systems, and can be grown alongside leafy salads to give a broad range of products. Herbs can also be used to flavour mixed salads to add value prior to retail.

Marketing Models

Salad crops can be produced on any scale, from a small local box scheme supply to developing novel crops and brands that would allow an entrance into supermarket supply chains, benefiting from unique selling points such as quality, freshness, novelty or Welsh origin. Starting a new hydroponics enterprise as an extension of existing business should be undertaken with an initial goal of exploiting existing marketing channels. Growers marketing edible produce through farm shops, veg box schemes or to local markets/consumers should focus on a combination of salad leaf products that can be sold in a ready-to-use state. Salad leaf can be sold in 100g - 350g bags for domestic use, or up to 1kg boxes for the food service sector. Watercress, chard and kale can be sold as bunched stems. Discussion with existing customers may provide an essential route to identifying product lines which would sell well. Fresh salads may also help to attract new customers, and as a market is developed new lines can be introduced. As a business becomes more experienced with salad production, other salad products can be included to further diversify through the identification of novel product lines.

Supply and Demand

A key benefit of hydroponic salads is the ability to stagger production to have a range of plant ages moving through the system at any one time. This allows growers to ensure continuity of supply (which is particularly important for the food service sector) as well as forward plan for periods of peak demand. The short growing periods for salads, particularly of single cut systems, means that timing production to customer requirements can be easily achieved with forward planning. Growing under protection, particularly under glass in the winter, will offer some season extension but significant out-

of-season production under lights is unlikely to be viable unless a strong market demand exists. Different lines may also see increased demand at different points of the year, with loose lettuce leaf showing strong summer demand compared with more little gem lettuce, chard / kale in the autumn.

4 Business Development

Hydroponically grown salads can provide an excellent addition to a growers business. The variety of products that can be achieved by growing salads alone will offer a broad range of products. It would be best to begin with a simple, limited, range of cultivars to establish a product base. As experience and the market develops, more product lines can be added to further diversify outputs in line with customer demand. New technologies are now allowing producers to grow vertically, making the best use of their land; with hydroponic leafy greens currently the most economically feasible crop grown.

Integrating Hydroponics into an Existing Business

Careful consideration must be given as to how hydroponics can be integrated into an existing growing business. Routes to market will be a key consideration – how can salads be marketed through existing channels, and what opportunities for new markets are available. This will also cover equipment and infrastructure. If potting up equipment is available, expanding to cover substrate grown microleaves would be similar than for businesses without this experience. Hydroponics can be established at any scale in a range of existing structures, so it may be possible to make greater use of current farm buildings, glasshouses or polytunnels. Due to the precise formulation of the nutrient solutions required for hydroponics, it is not possible to effectively grow salads to an organic standard. Therefore, if an existing business has an organic focus the use of chemical products will need to be accommodated. Cleaning, packing and chilling of produce will be required, so this would fit well with any existing mechanisms.

Biosecurity and Farm Assurance

Salad leaves are generally eaten raw, so extra care must be taken to ensure the produce is free from contamination. Why hydroponics avoids many of the potential risks of soil-grown production, it will still be important to have periodic testing of nutrient solutions, substrates and produce for potential pathogens. Membership of farm assurance schemes (e.g. BRC, SALSA) will include recommended procedures for fresh salad production, including pesticide residue guidelines.

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 resource management and efficiency of use, 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.

5 Salad Production – A Case Study

On a mixed nursery of glasshouses and tunnels leafy salads are grown for local outlets, primarily the restaurant trade. They have worked closely with their clients, encouraging chefs to visit to see the growing crops and discuss new lines which can be researched and trialled. Alternative routes to market include wholesale suppliers, and opportunities also exist to supply your offering directly to the customer by targeting local venues. The crops currently grown include rocket grown in peat based growing bags and watercress grown hydroponically in perlite alongside a wide range of specialist items from *Mertensia* (vegetable oyster or oysterleaf) to edible flowers.

Watercress and rocket are started as seeds sown direct into module trays that are later planted into their final stations ready for cropping. The watercress has a through flow system and nutrient solution is supplied by irrigation pipes in the perlite. Standard proprietary bag feeds are used, with some elements (e.g. nitrogen) added in response to crop growth and demand. Both the cress and the rocket are semi perennial types that can be cut regularly, and if over supply is a problem they can be cut back hard and restarted. Watercress kept like this in cold glasshouses will cut for over a year. Without heat cropping can be expected to last from March to November and routine pest and disease programmes based on close attention the crops are employed.

Harvest is hand cut with stainless steel shears that have been adapted by welding a tray to the shears will help catch the crop as it is cut. The cut crop is put into a quality polythene bag and then chilled in a cold store to 3^0C. Typical unit sizes for watercress are as a 425g bag marketed for £4.50 to the food service trade, with harvest of 30 x 425g bags possible per hour with the adapted hand shears. This is much more expensive than the typical salad bags sold in supermarkets but customers looking for high quality, local produce are happy to pay the additional costs, especially for speciality vegetables.

It should be possible to generate a decent profit from 0.4 Ha of tunnels and glasshouses and this could provide income from March to November. Local shops, delicatessens and restaurants form a core customer base, but R&D on new crops is always ongoing. The market is niche but quite strong and if quantities are produced on a regular basis, then additional market space through wholesalers can be achieved.

Microleaf or punnet salads plus baby vegetables are also becoming popular especially in restaurants for garnishing (**Fig. 7 & Fig. 8**). These mixes vary from beets and chards through to Asian brassicas and other crops, a wide range is available to suit customer requirements. Here the seed is sown on a capillary pad so there is no soil or substrate contamination and the punnets are placed in a germination cabinet or room after sowing and are then moved out into growing rooms or polythene/glass structures for maturation. The crop can be complete in 14 days and is usually sold by the punnet so the buyer can harvest fresh produce as it is required.

Fig. 7: Microleaf cut salads and salad punnets

Fig. 8: Baby vegetables produced for the restaurant trade. Good quality, green leaf is important for presentation on the plate

6 Next Steps

The decision to develop a hydroponics venture must be based on a strong analysis of the potential market for leafy salad products, 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 leafy salads, 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, but shouldn't be considered as exhaustive, nor should they be considered as recommendations over other suppliers in the market.

SEED SUPPLIERS

CN Seeds
Main Street
Pymoor
Ely
Cambrigeshire CB6 2ED
Tel. (01353) 699 413
www.cnseeds.co.uk

E.W King & Co
Monks Farm
Coggeshall
Kelvedon, Colchester
Essex, CO5 9PG
Tel. (01376) 570 000
www.kingsseedsdirect.com

Elsoms Seeds
Spalding
Lincolnshire
PE11 1QG
Tel. (01775) 715 000
www.elsoms.com

Moles Seeds (UK)
Turkey Cock Lane
Stanway
Colchester
Essex CO3 8PD
Tel. (01206) 213 213
www.molesseeds.co.uk

Pro-Veg Seeds
6 Shingay Lane
Sawston,
Cambridge
CB22 3SS
Tel. (01223) 499 131
www.provegseeds.com

Tozer Seeds
Turkey Cock Lane
Head Office
Pyports, Downside Bridge Road,
Cobham, Surrey, KT11 3EH
Tel. (01932) 862 059
www.tozerseeds.com

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

Bulrush Horticulture Ltd
Newferry Road
Bellaghy, Magherafelt
County Londonderry
BT45 8ND
Tel. (0287) 938 6555
www.bulrush.co.uk

CN Seeds
Main Street
Pymoor, Ely
Cambrigeshire CB6 2ED
Tel. (01353) 699 413
www.cnseeds.co.uk

ICL
Boulby Mine
Loftus
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, (P): POLYTUNNELS, (C): CONSUMABLES

Bridge Greenhouses
Chalk Lane,
Keynor Lane,
Sidlesham, Chichester,
West Sussex,
PO20 7LL
Tel. (01243) 641 789
www.bridgegreenhouses.co.uk
(G)

Cambridge HOK
Wallingfen Park
236 Main Road
Newport, Brough
East Yorkshire
HU15 2RH
Tel. (01430) 449 440
www.cambridgehok.co.uk
(F), (G)

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

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

HBS Design
Heron Buildings
Plaxton Bridge Road
Woodmansey
Beverley
East Yorkshire. HU17 0RT
Tel. (01482) 679 344
www.hbsdesigns.co.uk
(F), (G)

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

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)

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
(P)

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