Compendium for the report on:
“Intensive Berry Production Using Greenhouses, Substrates and Hydroponics. Is this the Way Forward?”

“Note, this compendium should be accompanied by Nicola’s final report, which is available on the Nuffield International website, under reports”

A report for

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2014 Nuffield Scholar

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Protected Berry Cropping Structures for Berry Production

Hail Net

Hail net is high tensioned mesh similar to shade cloth that is manufactured in various strengths, thicknesses and fibrous materials. The net is designed to hang suspended above the crop on wooden or steel poles. The net's purpose is to protect the crop from hail damage first and foremost, however it can also prevent excessive wind damage to the crops. Unlike bird netting, a hail net does not prevent bird access to the crop and fruit. Although it can act as a deterrent. The netting above the crop also creates a form of 'micro-climate' in that it maintains a slightly cooler temperature in hotter conditions and a slightly warmer temperature in colder conditions. It also slows down the air movement creating a slightly more humid environment beneath the net.

In hail prone regions, hail netting is necessary otherwise the berry crops, flower buds, leaves and fruit can be damaged or lost completely resulting in little to no harvest and thus the grower's return. Hail net does not prevent rain and the berry plants may still become wet and damage may occur from too much moisture. Harvesting may also be disrupted due to wet conditions which is disadvantageous.

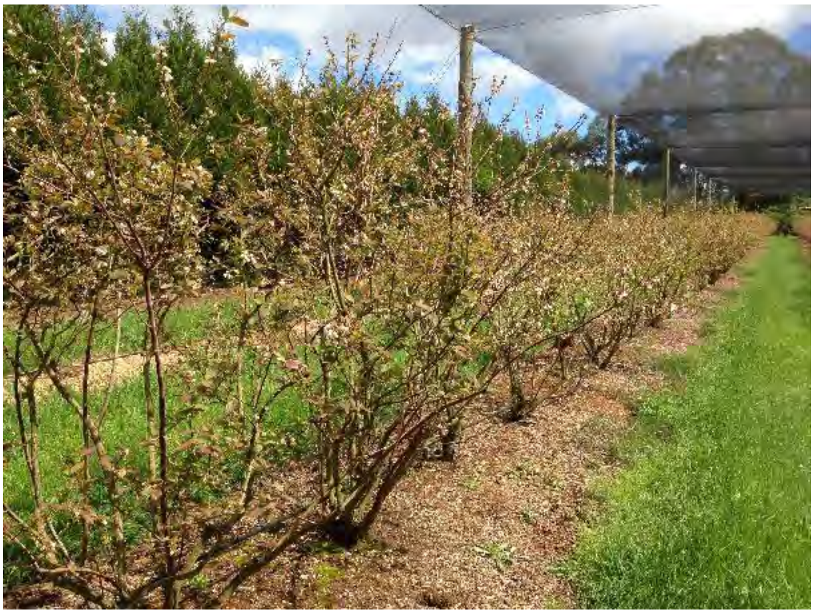

Figure 1 Hail Net over blueberries in Yarra Valley, VIC (Source: N Mann - October 2014)

Bird Net

Bird-netting is the most common form of protection on extensive production of blueberries as damage from birds can cause incredible crop losses affecting the yield and potential income of the grower.

Different coloured bird-netting is used around the globe and the selection of colour is usually a purely economic one. However, according to Retamales and Hancock (Hancock, 2012) blueberries can adjust their physiological processes and change to varying light levels offered by different shade-netting. There are advantages to selecting the correct colour and percent of shading for the specific climatic conditions and latitude that a grower is growing within and although fruit quality is not affected – there can be significant benefit to sustained increases in fruit yields (fruit weight) and the delays in fruit maturity which can be advantageous and profitable for growers (Lobos et al 2009).

The results from studies (Lobos et al, 2004) indicated that 50% white or 35% grey shade-netting had the best results because although 50% red net gave could results too – its colour greatly impaired the fruit colour. The 50-70% black net had the lowest impact on the yield and quality of the highbush blueberries. (Retamales et al 2004) In another study on Optical Manipulations of Insect Pests for Protecting Greenhouse Crops by Dr. David Ben-Yakir of ARO, The Volcani Centre, Israel presented at the Canadian Greenhouse Conference on 8 October 2014– found that yellow and pearl coloured netting attracted the insects likes aphids and thrips but these insects never penetrated the net to access the crop but remained on the cladding whereas there was more insect penetration under black and red net.

Like hail net, bird netting does not prevent losses from rain and wet conditions which causes diseases like botrytis and harvest may be disrupted due to wet fruit and labour unable to work in the rain. Most netting costs between $35,000-$50,000 per hectare for cables, poles, netting and construction. (Wilk, 2014)

Figure 2 White Bird Netting Over Blueberries (Source: N Mann New Zealand December 2014)

Low Tunnels

Low tunnels are another basic type of protection for berry production and mostly used in outdoor production of strawberries. The low tunnels are either made out of fleece or plastic. The protection may only be draped over the crop, as the covers are light and not much damage is sustained by the weight of these covers. Alternatively small hoop structures (either steel or bamboo) are erected over the beds and the plastic or fleece is secured over the hoops and suspended above the berries. The main purpose of low tunnels is to protect the crop from frosts, rain, birds and insects especially when it is at an immature and delicate stage of growth. This method of low tech protection is to assist with and brought to an advanced stage to coincide with ideal conditions, when this occurs these covers are removed and the strawberries flourish in the natural environment. Again the protection is used for timing and to enable growers to come into production earlier. Low tunnel technique is also adopted in some high tunnel structures. For example in Scotland and parts of the UK – it was observed that fleece covers were placed on young berry crops to maintain as much temperature as possible and protect the berry crops from the extreme cold which could damage or further delay spring growth when the temperatures began to warm up.

Another use for low tunnels is in organic berry production to protect against pests whilst the crops are immature and just establishing themselves – during this period the young berry crops can be susceptible to invasion or infection.

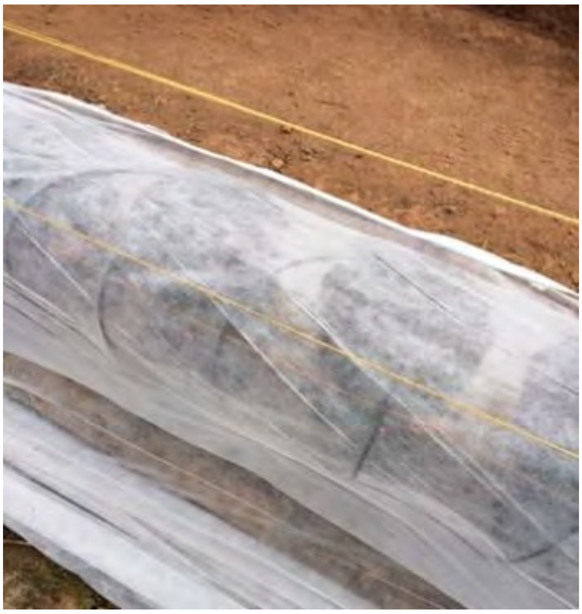

Figure 3 Low Tunnel Fleece covering young raspberry plants. (Source: N Mann United Kingdom April 2015)

High Tunnels

This is the most commonly used greenhouse structure around the globe for protected cropping of berry crops. These structures are relatively easy to erect; require little to no planning approval as they are generally considered temporary structures; they are fairly robust in nature and low cost per m2 compared to multi-span greenhouses and glass greenhouses. There are numerous suppliers of high tunnels around the globe and there are just as many variations to the height, width, length, steel used, plastic thickness and gutter options of these tunnels. The level of the sophistication of the high tunnels varies greatly and it was observed that anything and everything is possible within these types of structures, some are fitted with automatic sides, doors and top opening vents powered by solar power to other tunnels just being the most basic with plastic covers manually attached and removed depending on the season and what outcome the grower is trying to achieve. Most high tunnels are used to keep the berry crops dry so that fruit does not get wet and damaged from fungal diseases like *Botrytis cinerea.* Also fruit can be harvested regardless of rain outside the tunnel which would otherwise mean harvesting may have to be delayed until the crop dried.

The tunnels may deter birds but unless they are totally sealed birds may still access the crop and berries causing extensive damage and losses. Some growers have put bird netting over the entire high tunnel structure at great expense to maintain a bird exclusion zone.

Figure 4 High Tunnel Structures over Strawberries. (Source. N Mann Spain March 2015)

Figure 5 White Bird Netting Over the Entire High Tunnel of Strawberry Crop. (Source: N Mann New Zealand December 2014)

Figure 6 High Tunnel With Plastic Covers Removed. (Source. N Mann Scotland April 2015)

Growers have the option to remove the covers to slow the crop down and delay the harvest period by maintaining the crop in cool conditions for as long as possible. The same technique may be used at the end of the season to stimulate and force the crop into winter dormancy earlier by removing the covers as the weather cools.

Figure 7 Solar Powered Slide Opening of High Tunnel. (Source: N Mann Haygrove UK April 2015)

There are steps to improve the control of high tunnels with electric and solar-powered systems. Computer-controlled equipment to open and close the sides, doors and vents (if available) is beneficial because if this is done by hand these can be slow, tedious and suck up man-hours which in countries like Australia is not realistic.

Cost for the most common high tunnels from Haygrove® and Quiedan® usually range between \$80,000 - \$85,000 per hectare including the supply and erection on site. (Wilk, 2014) Which begs the question of why grower do not invest the extra money for high tunnel over netting when the benefits are:-

- 35-50% increase in yield of Class one berry produce
- decrease the risk of severe weather events
- increase labour productivity as no weather disruptions to work activity
- decrease pesticide and fungicide use
- earlier crop development
- save water by reduction in evapo-transpiration

(Berry, 2015)

Figure 8 Laura from Haygrove UK demonstrating manual side opening of High Tunnels. (Source: N Mann UK April 2015)

Telescopic Tunnels

Telescopic tunnels are a variation on the normal high tunnels in that the legs of the tunnels can be extended or retracted depending on the season and how the grower is wanting to manipulate the crop. Basically the entire height of the tunnel can be lowered or heightened. These are used mainly going into winter to maintain temperature of the berry crop as close to optimal temperatures as possible with minimum stress from severe cold conditions, the structure is lowered totally just above the crop. Incidentally, there some growers who have their table-top strawberries on telescopic table-top stands too – thus enabling the grower to lower the height of the entire crop to ground level where it is warmer in the extremely frosty months. In conjunction with the lowering of the tabletops and the entire structure– fleece covers can be placed on the crop as an added insulation and protection strategy against the cold. Once the conditions begin to warm up the structure may be gradually heightened to maximise the growth and warmth within the structure giving more control of the rate of growth and keeping temperatures and humidity as optimum as possible. The only disadvantage of telescopic tunnels and benchtops is that they are very labour intensive if the system is not automatically controlled. Approximately 50 man hours per hectare for lowering using a team of 18 people and 59 man hours per hectare to lift the telescopic tunnel for a team of 18 people. (Haygrove, 2015) With all this effort the crop can be advanced by a maximum of 2 weeks which could be mean a significant difference in return for the grower (Laura, 2015)

This type of control and manipulation of climate can be easily attained from a more sophisticated greenhouse structure but at a higher cost initially but there would be significant labour saving in the long run.

Plastic Tunnels with Shade Netting

In Portugal at Sunshine Fruit in the Algave it was observed that 40% shade-netting was put over the plastic high tunnels for the 3-4 months in the height of summer to increase the quality of the raspberries which would have otherwise suffered damage from pro-longed exposure to high radiation in the long summer days which can cause white/bleached drupelets. (Hall, 2013). Hugo from Sunshine Fruit said the 40% shade-netting could go on top of the plastic tunnels as soon as temperatures reached 27^{0}C as there was adequate daylight hours and the extended day-lengths had an adverse effect on the quality of the raspberries (soft skins and pale fruit) therefore the shade-netting was essential in this region. (Hugo, 2015)

Greenhouses

"A greenhouse is one part of an integrated intensive plant production system. It is a critical component that dictates the success or otherwise of the business enterprise. A successful greenhouse based business is dependent on achieving the right balance between the horticultural, engineering and financial aspects of the facility." Explains Geoff Connellan at the PCA Conference 2015. (Connellan, 2015)

Mexico is a good example of a country that is embracing protected cropping as shown in Figure 15 below. (Olson, 2013)

BERRY	Protected agriculture share of production	Ave. labour requirement (worker/ha)
Strawberry	50%	7
Raspberry	90%	7.8
Blackberry	40%	10
Blueberry	50%	7.8

Figure 9 Industry estimates on protected agriculture's share of berry production in Mexico and average labour requirement per hectare of protected installations. (Source: Olson 2013)

Multi-Span Plastic Greenhouses

Although not commonly setup for growing berry crops initially, there is a trend in various countries where small and medium sized multi-span plastic greenhouse growers are adapting these greenhouses to grow berry crops from previous crops of flowers, cucumbers, capsicums or tomatoes which are becoming less viable for the small to intermediate growers (Mann, 2015).

Growers are attempting to grow strawberries, blueberries, raspberries and blackberries in these semi-sophisticated structures with positive results. There is greater air volume as most of these structures are at least 4 – 5 metres from ground level to the gutter with the more advanced structures being at least 6 meters to the gutter. A larger volume of air has the advantage of gradually increasing or decreasing in temperature as opposed to a smaller air volume that rapidly spikes in either situation. There is more control of the climate within these structures due to computer controlled automated vents, shade-screens, fans and other equipment common in these types of structures – some of the structures visited have inclusions such as pad and fan systems for added cooling, hydronic heating, fogging systems, etc – giving greater control and better manipulation of the environment to maximise yields and minimize stress through less disease pressure and thus increase and intensify production and yields. Birds are not problematic for the berry crops cultivated in these structures; IPM strategies can be successfully implemented providing greater control of pests without pesticides; crops do not suffer scorching; and pollinators (with the help of landmarks) can be very effective too within these improved structures. Opening vents and sidewalls (with birdnet already in place) can be advantageous for humidity and freedom of the pollinators to forage without hindrance.

Cost per m² ranges between A$85-A$100 but this varies considerable between suppliers and what is inclusion are offered within the structure and the quality of the steel and plastic. There are options to get much cheaper imported structures from places like China and to purchase second-hand structures which could greatly reduce the cost per m².

Figure 10 Seven Month Old Blueberry Bushes in Croft Multi-Span Greenhouse. (Source. N Mann NSW Australia August 2014)

Venlo Glasshouses

State of the art technology glass greenhouses are being used in various parts of the world (where adverse weather conditions and or seasonal change can be severe) to produce top quality, consistent crops of strawberries. These are high investment projects and in the Netherlands at Van Gennip Kwekery (photographed below) it was explained that the return on investment is targeted at 15 years. The technology included in this type of growing environment are:- hydronic heating, hanging gutters, pipe-and-rail, shade-screens, energy screens, supplementary lighting, CO_2 enrichment, foggers, precision irrigation, filtration and sterilizing system, recirculating and recycling of water and nutrients, air-flow fans and energy buffer tanks.

€300m² is a realistic cost for this type of structure and contents inclusive of the substrate, plants and their royalties. Control of the climate is precise for manipulating and creating optimum growing conditions to maximum plant health, development and eventual yield.

The response from the supermarkets to the production of strawberries from these projects has been extremely positive as supply is consistent, quality is first class and spray residues are minimal to non-existent.

Figure 11 Glass Venlo Greenhouse. (Source: N Mann The Netherlands March 2015)

Plastic Retractable Greenhouses

"Retractable roof greenhouses will cause a rewriting of crop management strategies, as well as guidelines for how greenhouses are built and where they are built." (Vollebregt, 2002)

Plastic retractable greenhouses are becoming a popular option globally albeit expensive for the berry sector and demonstrates a lot of potential. In particular, countries such as Australia stand to benefit immensely from this option due to a unique situation. Bumble bees are neither native nor currently present on mainland Australia and due to stringent quarantine regulations, they are forbidden from any form of introduction onto Australian shores. There are currently feral bumble bee colonies in Tasmania – but strictly prohibited for commercial breeding and utilisation. Bumble bees are globally acclaimed as superior commercial crop pollinators (Koppert Biological Systems, 2015) and unfortunately due to their "non-existence" here, European honey bees are an alternative option. (Steen, 2015) These European honey bees are ubiquitous in Australia but have been noted for their poor navigation when present under plastic-enclosed greenhouses. This retractable greenhouse provides an ideal solution to overcome this pollination issue, as the movable roof vents and side-walls fully withdraw to provide and allow for natural, direct sunlight to fully penetrate the greenhouse berry crop and environment creating no adverse impact on the European honey bees. (Tjeerd Blacquière, 2006)

There are also studies that support the full spectrum of sunlight and direct UV within a greenhouse can destroy some fungal diseases like botrytis and powdery mildew by reducing the “half-life” of the spores. (Len Tesoriero, 2015) Another advantage of extensive roof opening is that humidity can be reduced significantly and quickly allowing more air movement around the berry crop with the hot humid air exhausting and replaced by denser cold air. This reduces fungal diseases from sporulating in high humid conditions which is a common occurrence in normal enclosed greenhouses. (Len Tesoriero, 2015)

Benefits of retractable greenhouse growing systems (Powerplants, 2015):-

- Reduction in fertilizer usage – as roof tops close during rainfall reducing leaching of nutrients
- Reduction in risk from catastrophic loss – from major disease outbreak because crop management is supreme; from extreme weather even cyclones with wind speeds up to 200kph as the rooves and sidewalls retract in minutes;
- Reduction in fungicide use between 50-100%
- Reduction in growth regulator usage between 50-100%
- Reduction in pesticide use between 10-100%
- Reduction in herbicide use between 50-100%
- Increased life of the roof covering

Figure 12 Hydroponic Strawberries. (Source: Cravo Website 2015)

Polycarbonate Retractable Greenhouse

The retractable greenhouses made from polycarbonate are extremely robust structures and able to withstand severe wind and climatic conditions which plastic structures cannot tolerate. The vents are vertical opening allowing rapid release of humidity and increased air exchange as well as allowing natural light to enter the crop. An added benefit from retractable greenhouse rooves is the exposure of the plants to natural light which stimulates the strengthening of the cell cuticles of the plants to become stronger and more resilient to disease as they are less permeable and susceptible to infection. “Retractable roof greenhouses appear to optimize both rate of photosynthesis and the reduced levels of beneficial plant stress to ensure that it develops the strength, disease and insect resistance not present when plants are grown inside conventional greenhouses". (Vollebregt, 2002) Additionally, "plant responses in retractable roof greenhouses include stronger root systems, reduced internode lengths, thicker cuticles, fewer root and foliar diseases, fewer insect pests, and less stress and show less shock following transplanting." (Vollebregt, 2002)

Figure 13 Polycarbonate Greenhouse with Retractable Roof. (Source. N Mann Watsonville, USA October, 2014)

Glasshouse Retractable Greenhouses

Considered the "Rolls Royce" of protected cropping structures – the Glasshouse with a Retractable Roof gives the grower the ultimate in climate control – these structures are fitted with all the latest growing tools like hydronic heating, pipe and rails, shade screens, energy screens, foggers, misters, CO^2 injection and fans. An added advantage is the ability to get natural sunlight into the structure and onto the crop and to exchange air quickly with the outside environment. A disadvantage of this system is the access from birds and insects is made possible through the open roof tops. Incidentally some beneficial insects and pollinators may escape through the rooftops too – this can be counter-acted with bird or insect netting.

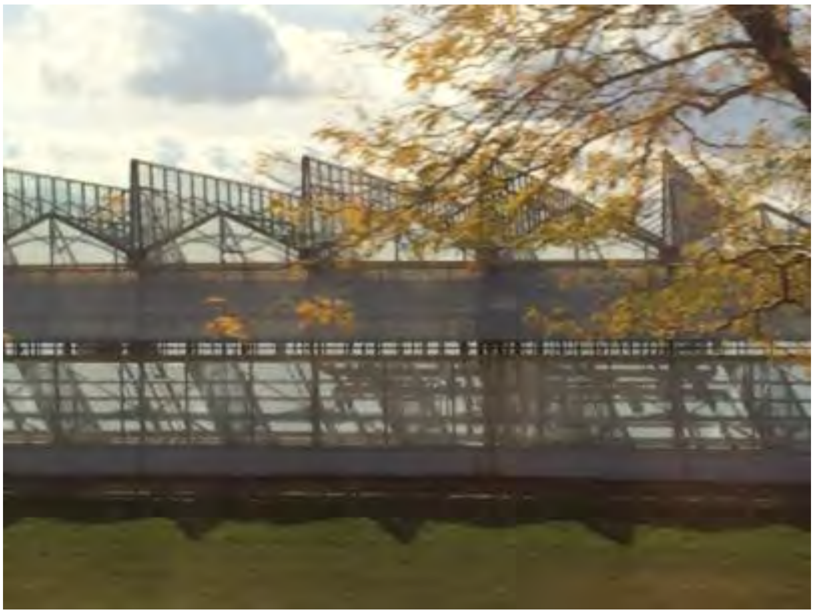

Figure 14 Glass Greenhouse with Retractable Roof. (Source: N Mann Ontario, Canada 2014)

Substrates Used for Intensive Berry Production

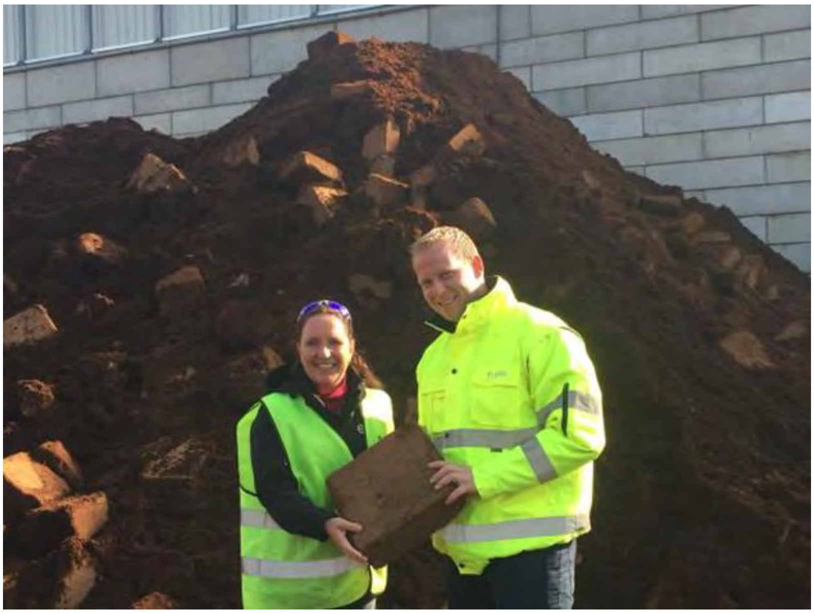

Figure 15 Nicky Mann with Jacco Hoogendoorn. (Source: W. Mann Legro The Netherlands March 2015)

What is a substrate?

A substrate is the substance or media in which the plants or organisms grow. In the greenhouse industry substrates refer to products which are mechanically altered either by heat, chopping, treating, washing, etc. to produce an insert substance which can be used successfully to grow plants hydroponically where all the water and nutrients will be dosed according to the needs of the plant and the stage of development. There is a multitude of substrates utilised to grow berry crops and they vary greatly. Substrates normally have good moisture retention properties, high air porosity and a density to offer support to the roots to anchor the plant in a vertical position. For the purpose of this report the following have been selected to evaluate.

Why use substrates?

The use of substrates such as coco-peat, rockwool and others has emerged to enable growers to cultivate berries in regions where the soil is unsuitable for berry production. For example in some parts of Chile, the soil pH is too high and there is a lack of ericaceous mycorrhizae (Gough, 1994) for the successful cultivation of highbush blueberries. This is also the case in the Algave region of Portugal where the pH of the soil can be as high as 8.5, which makes it impossible to cultivate blueberries, raspberries, strawberries and blackberries. (Hugo, 2015) The growers here have adopted substrate production to enable them to utilise the positive climatic conditions of the region to produce berry crops where the pH of the soil would previously have been prohibitive.

Growers can select and combine specific formulations of substrates, which are ideal for the particular berry variety they have elected to produce. Control over the nutrients and watering added to this carefully selected substrate can be precise and measured for the climatic conditions, the plant's needs and stage of growth or development. Substrates eliminate the need to worry about variation of soil type and structure within a cultivation area. This consistency makes the management easier and more refined, resulting in even crop growth, health and production.

Propagation Mixes

Berry plants require different nutrients when they are younger and have developing roots. The propagation mixes tend to be finer to encourage the early root development and the uptake of necessary nutrients.

Sand

The majority of the main berry producing countries like Spain, Portugal, Morocco, Peru, Chile, Argentina, Mexico, California in USA are growing blueberries, raspberries and blackberries extensively in sandy soils. The sand is usually sterilized with chloropictin or some other soil fumigant before use. These soils are free draining, easy to sterilize[1] and fairly easy to add nutrients too – however, irrigation has to be regular to keep the plants from drying out and going into stress.

[1] With phase out of Methyl Bromide sterilizing all soils including sand will become more prohibitive.

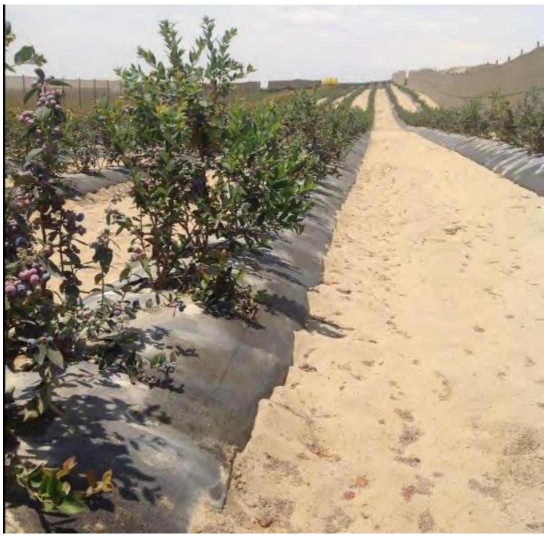

Figure 16 Southern Highbush Production of Blueberries in Sand in Peru. (Source. World Berry Congress, Rotterdam March 2015)

Sawdust

There is a large company in New Zealand utilizes sawdust as a growing media for hydroponic blueberries and with significant results. However, with the crop being relatively young it is hard to determine how the results will continue to be into the near future of 3-5 years' time and whether the sawdust retains its structure or collapses and thus inhibits growth and ultimately yields. However, using sawdust from pine trees may provide the blueberries with the acidity they require and hence the success at the moment.

Pine Bark

Pine bark is used by some growers for blueberry production and this media can provide acidity which the blueberries thrive in – depending on the size of the bark and its source – it can create difficulties for the growers as the density and porosity of the chips of bark can vary greatly and create issues with limited permeability to the feeds or releasing the feeds back to the rootzone at inconsistent intervals causing fluctuations and difficulties associated with control of the rootzone. Some berry growers to use pine bark as an effective mulch on top of other substrates like coco-peat to deter weeds.

Coir

Coir is also commonly known as coco-peat and is made out of the mesocarp of coconuts – this fibrous waste material is left to breakdown and decompose for approximately 7 years before it is put through a process to mill it up. The size of the milling or chopping process will define the size of the end product. Below are some photographs to show the varying sizing of the coir from very fine dust to Fraction 1, Fraction 2 and finally Fraction 3 which is obviously a lot coarser.

Coco-peat stood out from the other substrates for intensive berry production for the following reasons:

- Exceptional capacity for absorbing and distributing water,

- Shows virtually no degradation, making it more stable than other organic substrates,
- Retains its good drainage capacity longer than other substrates,
- Coco-peat's high air percentage caters for rapid root development,
- Coco-peat is highly stable and is not modified by nor does it modify the soluble nutrients and fertilisers applied to the plants,
- Renewable form of growing media
- Totally biodegradable when it is no longer needed for growing purposes,
- *Trichoderma* is naturally contained within coir, (Hoogendoorn, 2015)
- Could be easily blended with Irish peat, perlite and bio-stimulants for optimum results,
- Adaptability - the size of the coco-peat can be selected, from fine to coarse and anything in between, and
- Coco-peat fibres facilitate excellent lateral water distribution for the benefit of the berry roots.

It was interesting to observe at Haygrove UK that 95% of their berry fruit production is in substrate (mainly coco-peat) and in the last 10 years there has been a 50% increase in production due to improved varieties and the use of substrate. There has also been a significant increase in class one quality fruit due to the new production systems. The owners realised that land is in short supply so had to utilize the area already owned and under production to produce more using substrates and tunnel cultivation. (Laura, 2015)

Faction 3 is big particles of coir and used for strawberries
Faction 2 is medium particles of coir and used for blueberries
Faction 1 is small particles of coir and used for smaller plugs, potting mixes and propagation mixes
Dust is not commonly used in mixes as the fine particles tend to sink to the bottom of the container and create a wet sludge which is not beneficial and usually encourages root borne diseases to develop.

Figure 17 Coir showing Fraction 1 on left and Dust on right. (Source: N Mann Legro The Netherlands April 2015)

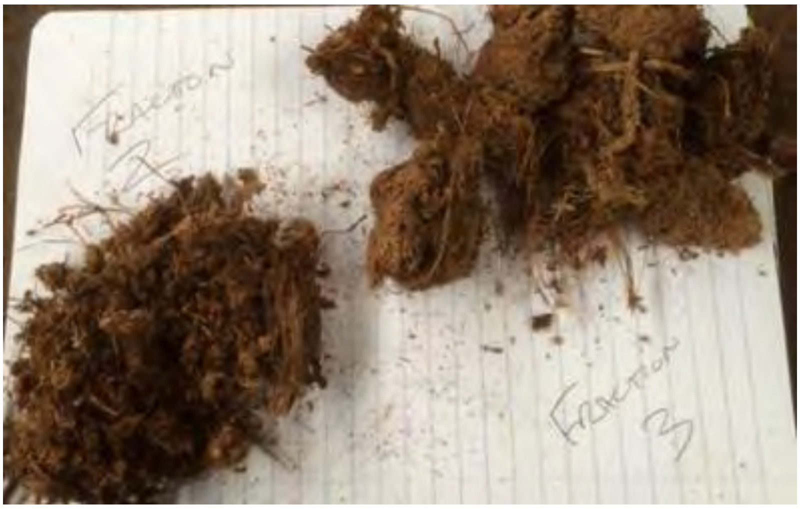

Figure 18 Coir showing Fraction 2 on left and Fraction 3 on right. (Source: N Mann Legro The Netherlands April 2015)

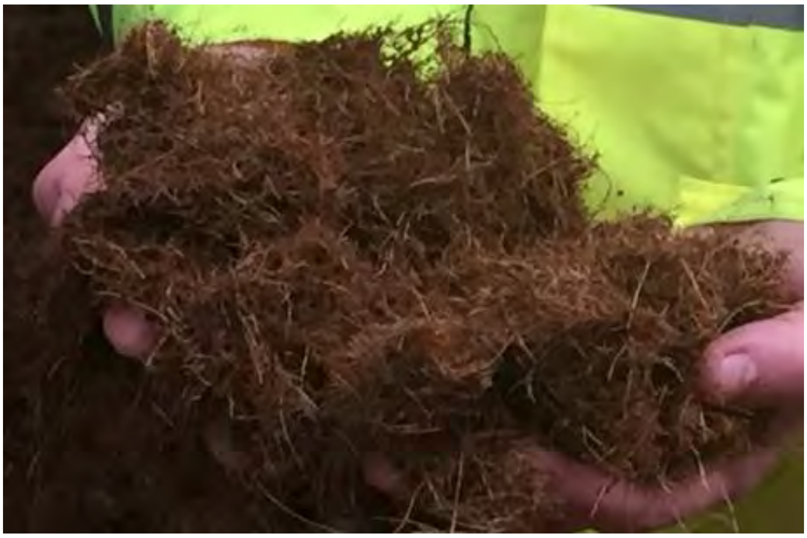

Figure 19 Coir Fibre (Source: N Mann Legro The Netherlands April 2015)

The fibres can be cut up in to varying sizes too but should always be included in the coir blend as the fibres assist with lateral movement of water in the substrate which assists with even water distribution within the container. There is an advantage of putting more fibres into a raspberry blend of coir for more lateral water movement and uptake by the vigorous root activity of these plants.

It is recommended to maintain a consistent particle size in the substrate used by hydroponic production of berries as this limits the finer/smaller particles sinking to the bottom of the container. The thick, coarse pieces of coir like the chips in a blend may be problematic as they absorb the nutrients from the fertigation feed and then release it at random intervals at the chip breaks down – this can be frustrating and confusing for a grower as the release of different elements can modify the rootzone and what is available to the plant other than the nutrients recently delivered in the latest feed. (Hoogendoorn, 2015)

Peat Moss

The Swedish and Baltic peat moss comes from the green sphagnum moss whereas the Irish peat moss is derived from the red sphagnum moss which makes it dark and heavy with excellent structure. The peat is mined and is not a renewable source of growing media. However, there are great advantages of using peat moss as a growing media especially for berry crops. In The Netherlands, one highly successful raspberry propagator uses a combination of Irish Peat Moss and Coir with a mycorrhizae additive for exceptional rooting results.

Figure 20 Left to Right: Swedish, Irish and Baltic Peat Moss. (Source: N Mann Legro The Netherlands April 2015)

Many blueberry growers are using peat moss in their blends for added acidity and structure for the blueberry roots which do not have root hairs. There are some growers advocating the addition of Peat Moss with the coco-peat as the Irish Peat has more structure, lasts longer and offers the plants an extended growing period in a containerized hydroponic system.

Vermiculite & Perlite

Vermiculite is one of the world's most unique minerals. A hydrated Magnesium Aluminium Silicate, it is lightweight, inorganic (incombustible), compressible, highly absorbent and non-reactive and is used in various of applications including potting soils and grow mixes. (Australian Perlite)

Perlite is the generic name for naturally occurring salicaceous volcanic rock, it is beneficial to add to a coir blend especially for blueberries (Hoogendoorn, 2015) or any berry crop which is going to be grown in the same media for an extended period of time as it is very stable, has excellent moisture retention but does not hold fertigation solution or individual elements.

Blends and Combinations of Substrates

Blends and combinations of substrates show the most promise for intensive production of berries in hydroponic systems as the media can be precisely selected for the best outcome for the plants. For example, SH Blueberries flourish in acidic root conditions so using a mixture of Irish peat moss, coir, perlite, *mycorrhizae,* buffered to the correct pH and charged with nutrients for the plants to commence growing immediately with a layer of bark on the surface as a mulch would be ideal.

Rockwool

Rockwool is a volcanic rock heated to extreme temperatures to fluff it out and it has been used in hydroponic systems for many years and is extremely popular with some growers as they feel it is the best media available for the following reasons:-

- Retains water
- Purity
- Holds air
- Convenient sizes for growing in
- Clean and convenient

Mark Massey from Greenworks says "whatever you do with rockwool multiplies itself, so if you get things right, the yields, the quality and plant health will be optimum and nothing compares to this media for precision. However, if the grower gets it wrong – the results can be disastrous with rockwool as it is not very forgiving."

However the following disadvantages need to be considered too:-

- Not environmentally friendly and hard to dispose of
- Dust and fibres are a health risk
- pH is naturally high which requires adjustment by the grower

Buffering of Substrate

Figure 21 Bulk Buffering of Coir. (Source: N Mann - The Netherlands April 2015)

What is buffering? It is washing out the excess salts that are naturally occurring in coco-nut husks. This is vital because the salts (sodium and potassium) are bound within the cells and if they are not washed out and if you add calcium or magnesium to the coir to feed the plants these salts are released and inhibit the plant growth. So once the salts are removed the substrate can be charged with the right base nutrient make-up to start using in a hydroponic system. Ready-buffered coir provides a big advantage to a grower as they can put the coir straight into the containers and plant the berries and starting applying normal nutrient feeds and growing the berry plants as normal. As opposed to receiving the coir – having to tediously wash it and then charge it will base nutrients so that it is now useable for growing anything in it. The ratio is normally 1 cubic metre of coir to 1 cubic metre of water for buffering and washing of the coir. There after it is charged with calcium nitrate depending on what crop is going to be grown in the media. This saves the grower time and in bulk buffering is done with precision over a huge volume of media.

Mycorrhizae and *Trichoderma*

Both these fungi are showing great potential in the berry industry as they form symbiotic relationships with the plants by increasing the uptake of nutrients by the roots.

In blueberries especially, *Ericoid mycrorrhizal* fungi helps them prosper in poor low pH soils, low in nitrate and calcium but high in organic matter. (Hancock, 2012) Most of the colonization occurs in the top 15cm of the soil. In a study of container-grown blueberry bushes inoculated with *mycrorrhizae* 6 out of the 7 cultivars increased total plant biomass. (Scagel, 2005). It was also noted that in highbush blueberry cultivars that fruited early in the season had higher levels of colonisation of *mycrorrhizae* in the root system than those that fruited later in the season. (Yang)

However, in hydroponic systems with good feeding programs these fungi may not be necessary as the plants are being administered exactly what they require. Although it is recommended that these be included in the base mix in the beginning to give the plant every advantage in the early plant development stage. *Trichoderma* is naturally occurring in coir. (Hoogendoorn, 2015)

Containers Used For Hydroponic Berry Production

According to the substrate company Fafard container production of berries is widely used in Europe for example in Switzerland container production of strawberries quadrupled between 2002 and 2009 from 10 to 40 hectares. Soilless culture is being swiftly adopted due to its high yields but what containers are recommended for intensive protective cropping of berries? The following were looked at:-

Plastic grow bags

Figure 22 Galuku Coir 20l Grow Bag with black inside and white on outside. Yarra Valley, Victoria - October 2013. (Soure: N Mann)

Plastic grow bags come in different sizes and are the cheapest and not surprisingly the most common container used for raspberry and blueberry production in Australia and New Zealand and usually supplied by Galuku with dry coir already inside the bag. The grower just needs to wet the substrate which expands and fills the bag ready for the berry to be planted. The white on the outside is beneficial in a hot climate like Australia as it reflects the light and reduces the heat on the roots.

Figure 23 Black Plastic Grow Bag (Black inside and out). Haygrove, Ledbury, UK - April 2015. (Source: N. Mann)

Black plastic grow bags are commonly utilized in colder climates – these bags are robust and cheap. The dark colour absorbs heats and keeps the rootzone warmer which is an advantage in the cooler climates. It is imperative to have plastic bags slightly elevated to ensure appropriate drainage for the berry crops so diseases likes phytophthora, pithium and fusarium do not develop at the bottom of the bags where moisture can accumulate.

Weaved grow bags and different sizes

Figure 24 25l Polyweave Bags filled with Coir Blend. (Source: N Mann - NSW January 2014)

Figure 25 Polyweave bags for hydroponic blueberry production. (Source: N. Mann NSW March 2014)

Polyweave bags are common in Australia and these bags photographed above have robust handles to easily move the plants about. There are 2 common sizes used for blueberry production 25l bags and 45l bags. The later gives a larger rootzone and buffered area and maybe advantageous in year 7 and above if the roots become too dense and matted – however, it must be noted that most blueberries have roots that are only 50cm deep and usually only shallow and with regular and precise hydroponic feeding the roots do not have to over develop to source nutrients.

Plastic pots

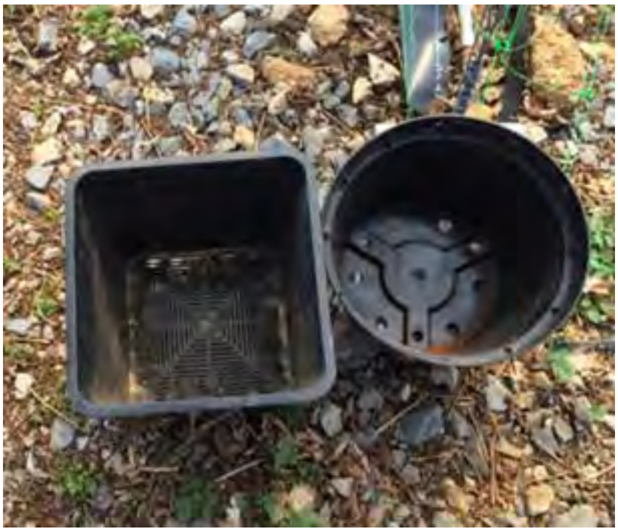

Figure 26 Square and Round Black Plastic Pots. (Source: N. Mann Portugal March 2015)

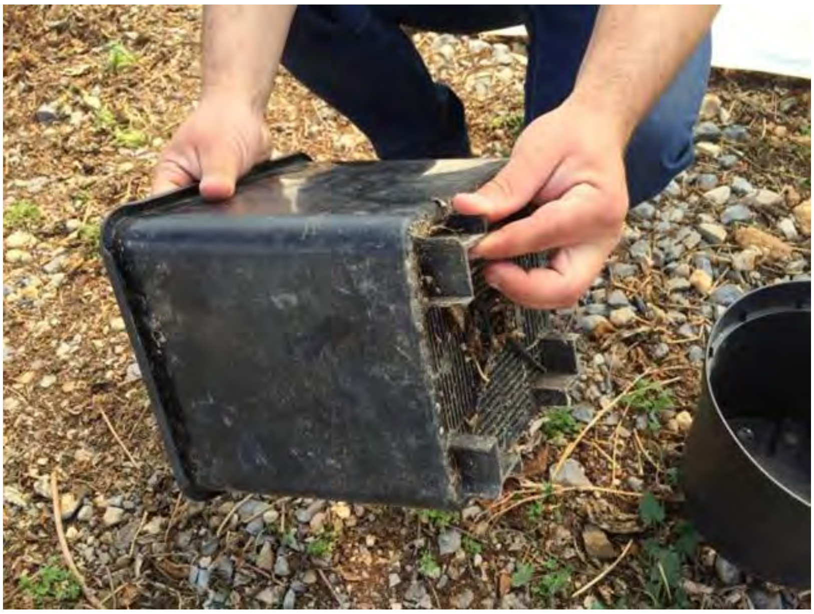

Figure 27 Plastic raspberry pots. (Source: N. Mann Sunshine Fruit Portugal March 2015)

The square 7.5 litre pots on the left were shown to encourage and maintain white healthy roots in raspberries (Hugo, 2015) compared to the same size pot on the right which was round. Both these containers were fitted with legs meaning they were held off the ground which is imperative for adequate drainage and to air prune any rogue roots.

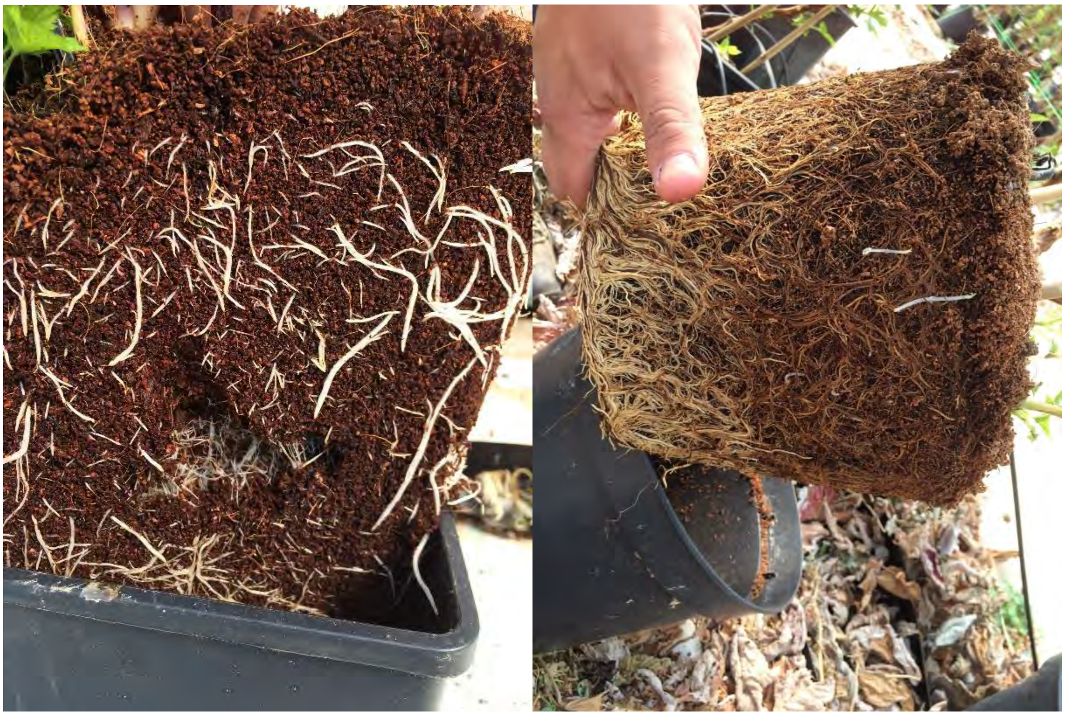

Figure 28 Comparing raspberry roots from the square pot with the round pot. (Source: N. Mann - Portugal March 2015)

There is a new range of pots on the market from PlantLogic® with excellent drainage properties especially for the hydroponic berry industry – these are just beginning to be used and the results are still being established but they look like they have potential to add benefit to growers.

Coir grow bags

Figure 29 Coco-Peat Grow Bags with Strawberries. (Source: N. Mann Tasmania September 2014)

Coir grow bags are the mostly commonly used container for table-top production of strawberries. They are robust, relatively cheap and very convenient to use. Plant spacing, dripper spacing and drainage holes can be pre-determined and selected on ordering from the coir grow bag provider. The major disadvantage of the grow bags is disposal of the plastic sleeves once the media has been exhausted. Some growers are re-using the coir for year 2 of strawberry production but the heightened risk of root borne pathogens increases profoundly – however, it is a risk some growers are prepared to take for the cost savings achieved by doing so.

Tubs

Figure 30 Recycled Polystyrene Broccoli boxes growing raspberries in coir. (Source: N.Mann NSW November 2013)

Re-cycled broccoli boxes made out of polystyrene can be used for raspberry production – they are relatively cheap and provide the added advantage of insulation against cold or hot temperatures. These particular boxes are filled with 2” of burnt ash beneath the coco-peat. This provides extra drainage ensuring the raspberry roots do not sit in wet, moist conditions which leads to ideal conditions for root pathogens. These robust boxes make use of a waste product which is looked upon favourably by consumers concerned with up-cycling & recycling – however, disposal of these containers does also provide a problem at the end of their life-span.

Troughs

Figure 31 Low white tubs growing raspberries in coir. (Source. N. Mann Spain March 2015)

These custom-styled white growing tubs seen in Spain provide another option for growing raspberries – the side drainage slits are a concern if there are no other drainage outlets underneath these tubs, as moisture and water can pool in the base of the tubs increasing the conditions for root infections. These containers are good examples of what little substrate is required to grow hydroponic raspberries especially if the grower is skilled and in-tuned with the crop. The white colour also deflects the heat and protects the roots from over-heating in warm climates.

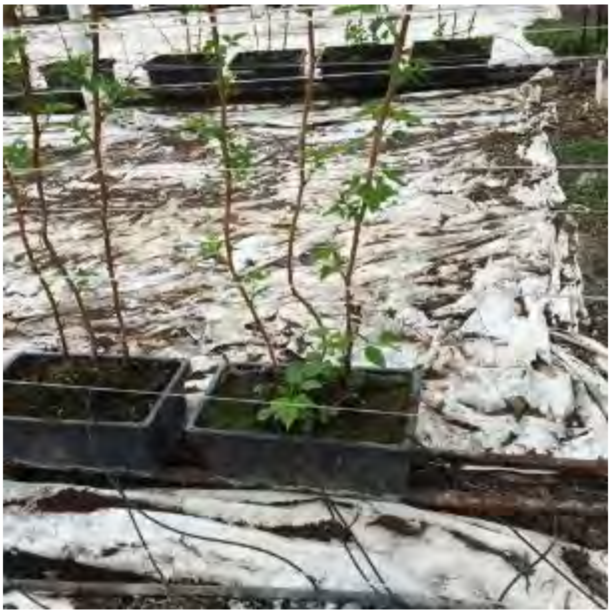

Figure 32 Shallow black tubs growing raspberries in coir. (Source: N. Mann Ireland March 2015)

These tubs are similar to shallow tubs seen in Spain – both used for raspberry production however these tubs are black and used in Ireland to absorb the heat to keep the raspberry roots as warm and active as possible. The white weed matting is also utilized to reflect as much light as possible back up to the plants above.

Figure 33 White troughs for strawberry production. (Source: N. Mann Keelings Ireland March 2015

The white troughs shown above are filled and mounded with buffered and blended coco-peat. This enables the strawberries to be planted at an angle, which makes the fruit easier for fruit pickers to see and pick from the plant.

Channels and Sausage bags

Some growers have gone to great lengths to lay down channels of core-flute or thick plastic which they have filled with substrate usually coco-peat to grow hydroponically in one long line or massive bed system. The biggest issue with this system is that the plants are no individually containerized so if there happens to be a root disease or infection, it will spread quickly and easily throughout the entire bed.

Weedmat-Bed System

This system is not to be mistaken from the normal soil bed system covered with weeding matting – this is an interesting deviation whereby the grower has carefully selected the blended coir mix and laid it on top of the soil and then covered it with weedmat. The plants and in this instance blueberries are planted directly into the coir mix which encourages the young plants to establish quickly and the drainage flows directly into the soil below. The older the bushes become their developed roots start growing into the soil below. This grower in Scotland saw a vast improvement from this system compared to his containerized growing system. The improved growth and yield on the identical age and variety of blueberry in this system was unquestionable compared to containerized production.

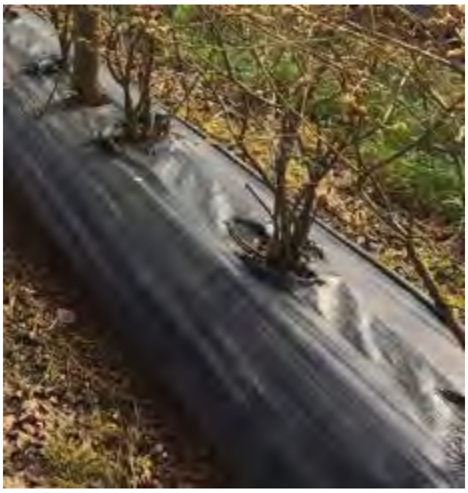

Figure 34 Blended coir and peat bed covered with weed mat growing NH Blueberries. (Source: N Mann Scotland April 2015)

Hydroponic Systems

PVC pipes as containers

Figure 35 PVC piping growing strawberries in NFT system. (Source. W. Mann NSW July 2013)

In Port Macquarie in New South Wales there is a very successful business utilizing PVC piping as containers for it's NFT/Aeroponic strawberry growing system. The method is simple and effective and increases the plant population considerably – however, there is no comparison to table-top production which is undoubtedly more efficient and effective. (Kwekerijen, 2015) This system works in this climate and for the purpose of steady pick-your-own trade. The crops look healthy, yield consistently and there are plenty of opportunity for all sizes of people to take advantage of picking strawberries by themselves. For this reason this system is ideal and effective for this particular market. The yield and continuous re-planting would make this system unviable for a different business model.

Hydroponic Systems Adopted by Intensive Berry Cultivation

There are 2 basic types of hydroponic systems – 'open' and 'closed' systems. The open hydroponic system means that the nutrient solution is distributed into the system and what the plants do not uptake is run off and not recirculated e.g. free drainage system. The closed system is the opposite with the nutrient solution being recycled and retained within the system e.g. recirculating system. It must be noted that strawberries and rubus are especially susceptible to root borne diseases and that is why the majority of growers select the open system because they afraid of recirculating diseases through the irrigation system. This is unfounded as a good closed irrigation system should have adequate sterilization to prevent diseases being passed through the nutrient solution. Within these 2 types of hydroponic systems there are variations of techniques of how the water and nutrients are delivered to the berries. Below are some of the different systems:

Nutrient Flow Technique / Aeroponics

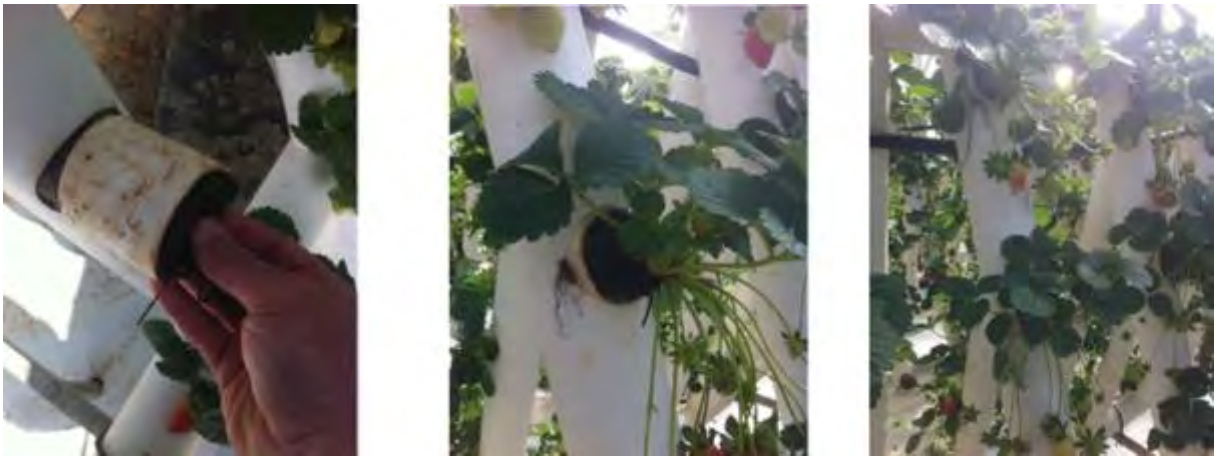

Figure 36 Strawberry production in PVC pipes with Aeroponic System. (Source: W Mann NSW July 2013)

Drip Tape or Trickle Feed

Figure 37 Drip tape under black plastic matting in raspberry production. (Source: N. Mann Spain March 2015)

This is the most common hydroponic system where the fertigation is fed through drip tape which is laid on the bed and usually under the mulch material. In some countries this is referred to trickle-feed especially in USA – it is cheap and effective but in warmer climates it is advised to have it below the mulch as water can be lost to evaporation. In New Zealand it was observed drip tape being as far as 1m from the plant on either side for mature blueberry bushes as this berry has wide spreading shallow roots. (Peach, 2014)

Individual Drippers

Figure 38 Northern Highbush Blueberries growing in black pots and blended media with 4 drippers. (Source: N Mann The Netherlands March 2015)

Individual drippers are the most common form of delivery of fertigation in containerized hydroponic berry production. The better performing berry crops observed around the globe had more than one dripper for pot and ideally 4 – to disperse the water and nutrients evenly for even spread of roots and even uptake up water and nutrients. In colder climates the black drippers are more common and in warmer climates the white micro-tubing is used to deliver the feed mix – as it reflects the light and so in turn keeps the temperature down of the incoming fertilization and irrigation.

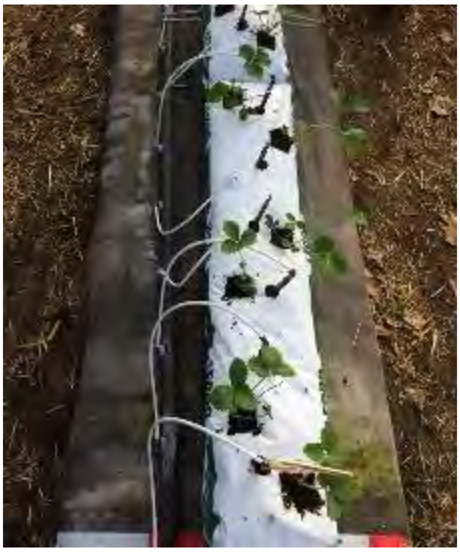

Figure 39 Coir slabs growing strawberries with white drippers. (Source: N. Mann The Netherlands March 2015)

Run to Waste

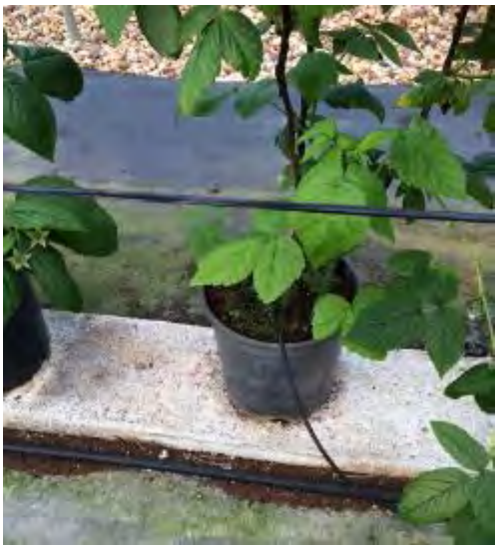

Figure 40 Raspberry in black pots elevated on polystyrene in a run to waste system. (Source: N. Mann The Netherlands March 2015)

It was surprising to see so many projects around the world with run-to-waste irrigation systems especially in the low-tech hydroponic berry growing systems. There are a couple of reasons why this happens :- water is cheap and plentiful, there is no infrastructure in place to capture and recycle the water, growers are growing to very little drainage (i.e. not watering for the normal 15-40% return), growers are concerned of spreading root pathogens through a recycling system so will not adopt this system, cost of setting up a recirculating system. Going forward this will have to change as water is a precious and valuable source and cannot be wasted, regulations will also prohibit leachate which is currently occurring, growers will become aware of the massive savings of recycling and re-using the nutrients. It is far easier to manager EC in a closed irrigation system than an open flow system. (Donnan, 2015)

Recycling of Water and Nutrients in Table-tops and Suspended Gutters

Figure 41 Suspended gutters growing strawberries in troughs. (Source: N Mann The Netherlands March 2015)

The more sophisticated the growing system the more sophisticated the irrigation, fertigation and control system that operates it. Closed irrigation systems are nothing new and common place in most greenhouse growing systems and becoming increasingly embraced by berry growers. All run off from the plants is collected, put through a sterilization system, nutrients and water maybe adjusted slightly depending on the plants needs and the climatic conditions within the greenhouse and then it is re-applied again and again with no waste. The only loss in the system is what the plants are taking up and making in vegetation or fruit. This system provides enormous savings for water and fertilizers use. (Donnan, 2015)

Raised beds

Figure 42 Raised beds of sand growing Strawberries. (Source: N Mann Spain March 2015)

Raised beds are the cheapest and most common form of hydroponic berry production. The soil is treated like a substrate and all water and nutrients are applied regardless of what is naturally occurring or available in the soil beneath the crop. It is a more complicated growing system as the soil in a field may vary greatly from one area to another yet the fertigation is all the same which can create uneven plant development, health and yield. Although a cheaper option of growing it definitely has its limitations especially that it requires sterilization at the end of each crop which is tedious and expensive and also because the sterilization kills everything in the soil (good and bad pathogens) if the berry crop does get a bad soil borne disease like *Phytophthora fragariae var. rubi* there is nothing in the soil to slow down it's progress and it can wipe out an entire strawberry or raspberry crop in days. (Eccles, 2014)

Spacing, Trellising and Support Systems Utilized in Protected Cropping of Berry Crops

T- Systems

The T-System is the most common support system for blueberries – it is simple and effective to keep the lateral branches supported and elevated off the ground especially when these branches are laden with fruit. The wires are parallel to each other and are on either side of the bushes. There can be multiple wires and differing height intervals but it is important to leave enough space between the wires for pickers to access and harvest the fruit. A drawback from the T-System is that it can bunch up the vegetation in the centre and not allow enough sunlight to reach the crown of the bush.

Figure 43 T-System of support in Northern Highbush Blueberries. (Source: N. Mann - Scotland April 2015)

V-Systems

The V-System is another option for supporting blueberry bushes but is also used for raspberry production too. The system allows sunlight to get to the centre of the crown of the plants stimulating new shoots from the base. Some growers secure the laterals to the wires to maintain a V-shape bush structure. In raspberry production using the V-System – alternate plants are attached to opposite wires on the “V” which advantageous for keeping the primo-canes spaced and neatly trellised. Raspberry harvesting in this system is simple as the fruit is neatly presented. The disadvantage of this system is the shading out of the bases of crops from the over-hanging vegetation which can cause some dampening off of the delicate stems.

Figure 44 V-System support for Raspberries. (Source: N Mann - UK, April 2015)

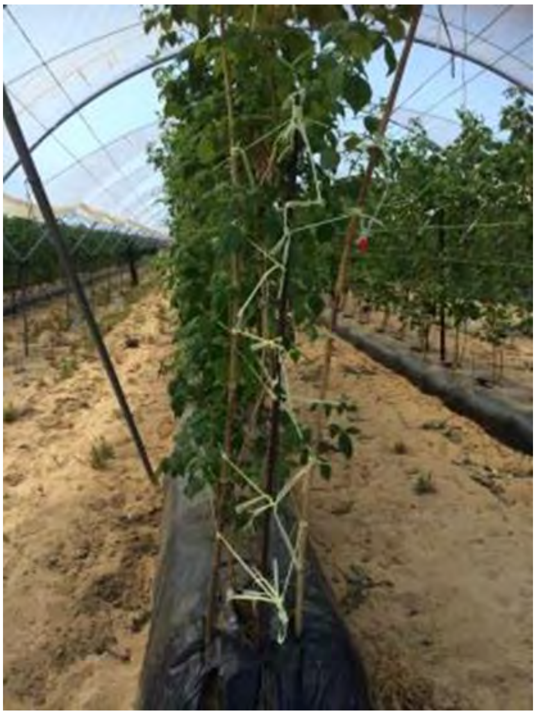

Figure 45 Cheap V-Trellising for raspberries. (Source: N. Mann Huelva, Spain March 2015)

Linear

In glasshouse raspberry production linear upright trellising is commonly adopted creating neat fruiting walls which are ideal for high plant density in the perfect growing conditions. Below is an image of raspberries with 2 primo canes in close pot-to-pot spacing.

Figure 46 Linear trellis system of raspberries with net. (Source. W. Mann Belgium March 2015)

Below is an image of blackberries being allowed to send up 6 canes, reducing the plant spacing but with positive results for a productive fruiting wall.

Figure 47 Liner system of blackberries along string. (Source. N.Mann - UK, April, 2015)

Support Netting and Wires

Large square synthetic netting is being commonly used for greenhouse raspberry production which provides excellent support for the raspberries keeping them neat and contained from the pathways. The netting can be suspended from the structure above and the raspberries can be weave through the netting as they grow it is supposedly a quicker trellising system for the labour. The large squares allow easy access for harvesters to reach the berries.

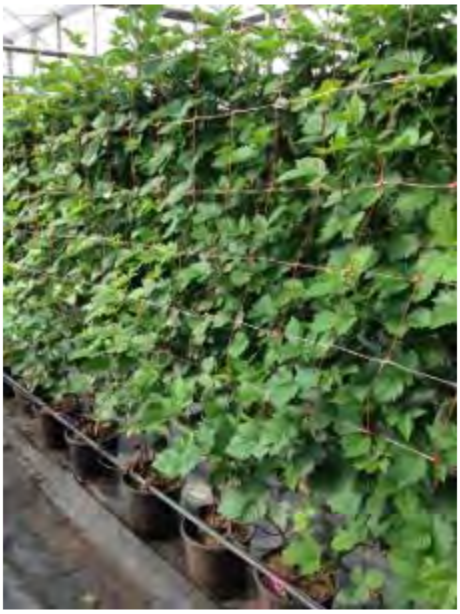

Figure 48 Raspberries trellised with synthetic netting. (Source: N. Mann Victoria October 2013)

Plant support

Table-Tops

There is a growing trend to cultivate strawberries on table tops under tunnels or greenhouse structures – single trough table tops are the most common especially in highly sophisticated glasshouse hydroponic systems. Firstly, the plants are completely off the ground and usually placed at a height that is ergonomically acceptable to the employees so that they can perform their duties effectively and efficiently without straining their bodies. This system alone results in a 30-40% labour saving at harvesting time from strawberries grown in beds on the ground and only 30 pickers are required per hectare as opposed to 50 used in the ground. (King, 2014) There are some varieties that suit the single table top system especially Amesti ™ which is a Driscolls® variety.

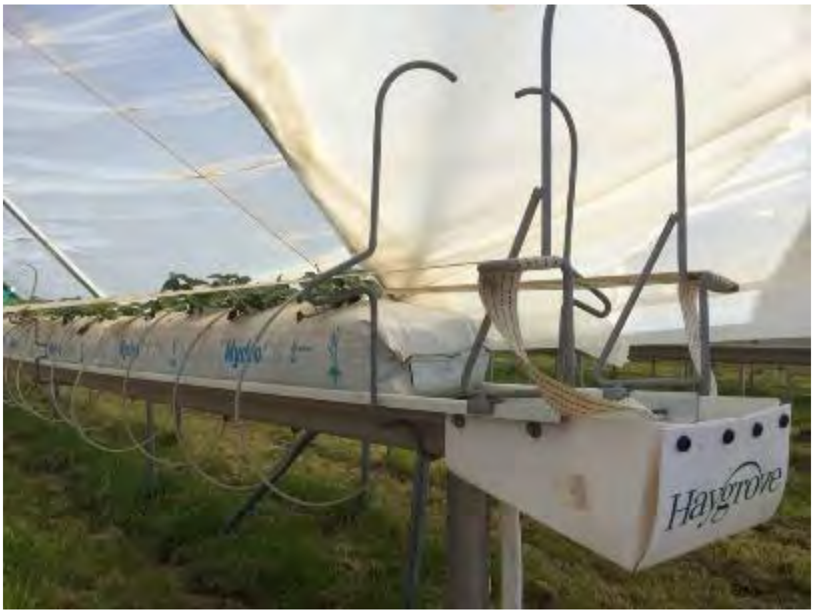

Figure 49 Single table tops under high tunnels. (Source: N. Mann Tasmania September 2014)

Double Tiers

At Haygrove® Ledbury in the UK – double table tops were utilized for cropping strawberries – obviously the plant density is higher in this case 30% extra plants per m2 however there was a 10% reduction in the effectiveness of labour in this system as it is more cumbersome and slower to access all plants for maintenance and harvesting purposes. (Laura, 2015)

Triple Tiers

Triple tier table tops are used to increase the plants per m² and especially useful when the grower is wanting to maximize yield on a small acreage, the example above is 8 strawberry plants per m² totalling 115,000 plants per hectare. The height and distance between the suspended troughs can be altered depending upon the variety being grown and the climatic conditions. Keeping in mind regions with high humidity and low light levels need to distance the rows accordingly – in order to get as much light to the strawberry plants as possible as well as ensure sufficient air movement around the strawberry plants so they do not get fungal infections. In Masterton, New Zealand after some experimenting Alan Bisset from The Wee Red Barn felt that 450mm distance between the top and bottom tier was perfect for the conditions in that region. The set-up also takes into consideration the ergonomic benefit to the pickers – so that they are quick and efficient and able to undertake harvesting day after day in peak season. (Bisset, 2014)

Figure 50 Triple Tier Tabletop Strawberries in Hamilton, New Zealand December 2014. (Source: N Mann)

There is also the potential to grow “day-neutral” variety strawberries on the lower levels of the table tops and grow a “June-bearer” on the top level which prefers more sunlight. However, the harvesting of the strawberries in these mixed variety levels can complicate the process.

Support for Fruit and Leaves

In hydroponic strawberry production it is vital to keep the leaves and fruit supported and apart so that fruit can be easily and swiftly harvested. Below is an image of the 2” webbing used for this purpose.

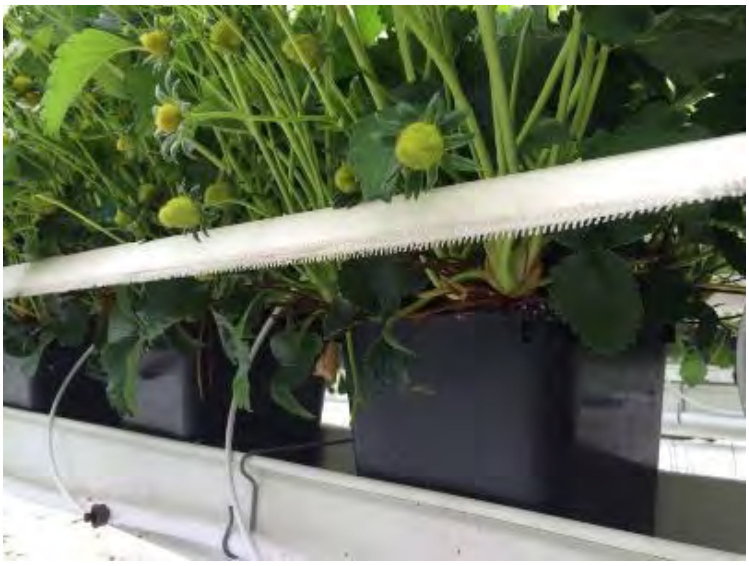

Figure 51 Webbing used for crop support in glasshouse strawberry production. (Source: N. Mann - The Netherlands, March 2015)

Below is another system used in The Netherlands where clear twine is utilized to keep the leaves off the fruit and then webbing to elevate the fruit slightly.

Figure 52 Glasshouse strawberry production with twine and webbing for support. (Source: N. Mann - The Netherlands, March 2015)

Weaving

"The Watsonville Weave" aptly named after the region of Watsonville the heart of rubus in California. This technique involves the blackberry primocanes being arched and secured to the linear wires – this method increases the surface area for floricanes to emerge along the primocane to present the fruit at a suitable and thick density for efficient and effective harvesting of the berries. This is method is adopted in outdoor and tunnel production of blackberries but is extremely expensive – approximately £2000 per hectare in labour costs to do this.

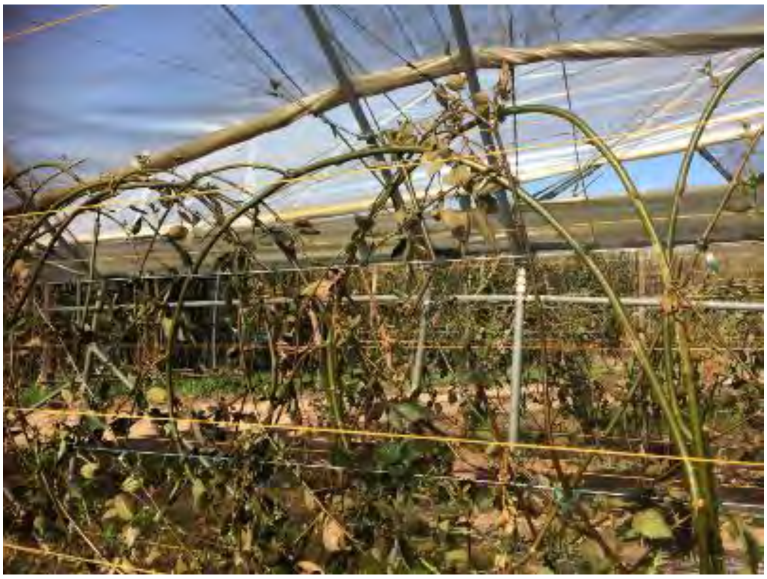

Figure 53 Weaving of blackberries in California. (Source: N. Mann Driscolls Watsonville, USA October 2014)

Bending

This is a technique - adopted from the hydroponic rose industry - being experimented with blueberries whereby the first main stem of the blueberry bush is gently arched over to force multiple lateral branches to emerge vertically to present the fruit for easy harvest in the first year. The laterals should be pinched when they reach 40-50cm in height. This bush management makes the plant architecture more compact and supposedly productive with good size fruit. (Mann, 2015)

Figure 54 Bending blueberries forcing vertical laterals. (Source: N. Mann NSW May 2014)

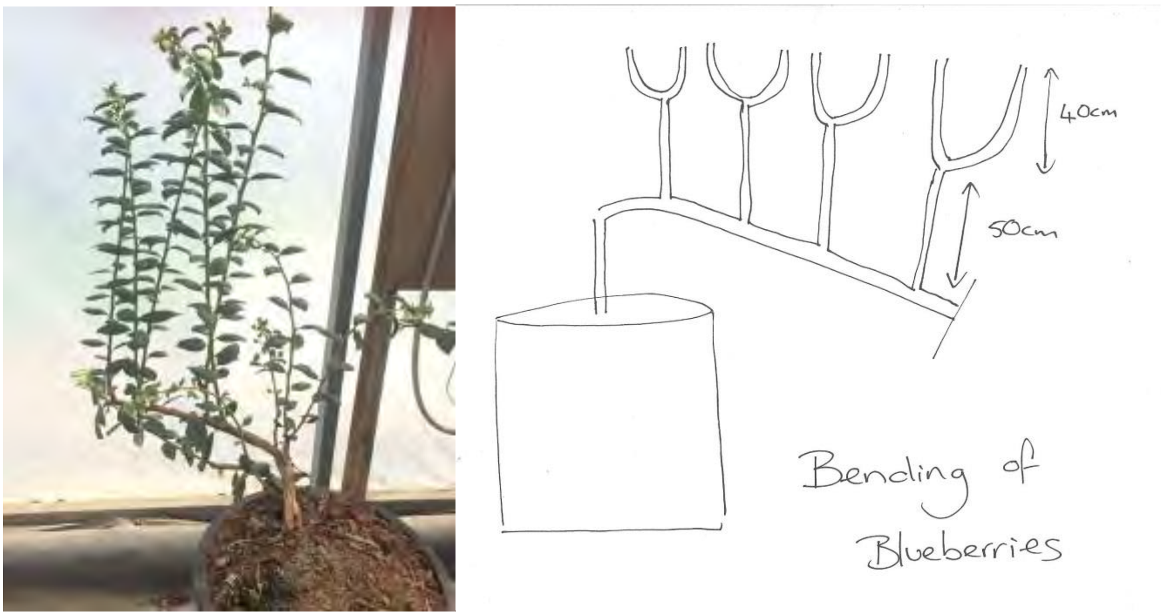

Figure 55 The 6 month old blueberry bush after bending technique applied. (Sourced: N. Mann NSW August 2014)

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