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Cranberry Production

- The potential for using hydroponics -

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Cranberry Production -
The potential for using hydroponics

by Christina Dennis

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Foreword

Cranberries (*Vaccinium macrocarpum*) have proven health benefits in the urinary tract, cardiac and oral health areas, and have documented anti-cancer and anti-ulcer properties. To date, no synthetic substitute for Cranberry has been developed. Given the rise in consumer awareness of the benefits of including functional foods in the diet to improve and maintain wellness, the medicinal properties of cranberries create an opportunity in Australia to produce and market fresh cranberries in an environmentally sustainable manner to meet the demand for fresh functional foods.

Cranberries have traditionally been grown in natural bogs, where the moisture and decaying organic matter create ideal growing conditions for these plants. Large scale production occurs in natural and artificially created wetlands which would not be viable in Australia; however cranberries are likely to be ideally suited to hydroponics.

The project aimed to identify the hydroponic system that would be most suitable for cranberry production, identify crop management strategies and provide an indicative cost of the system.

This publication summarises the evaluation of hydroponic cranberry production potential, which found that production would be more suited to regions of Australia with moderate summers, adequate rainfall and some winter chilling. Microclimate factors have an effect on flowering and fruiting, and whilst they can be manipulated in an enclosed environment, this dramatically increases the cost of the system.

Crop management strategies also have significant effects on production, and could be further investigated in a longer term project. The time lag with flower-set means any effects on flowering are not seen until the following season. These could be better investigated over a 5-8 year intensive study in a suitable climatic zone, using the management strategies elucidated through this project.

This report, an addition to RIRDC's diverse range of over 1800 research publications, forms part of our New Plant Products R&D program, which aims to facilitate the development of new rural industries based on plants or plant products that have commercial potential for Australia.

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Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

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All original photographs and artwork in this publication have been included with the permission of Bioden Pty Ltd

Finally, thanks to Dr Jason Dennis for technical guidance throughout this project and comments on the reports.

Technical Terms and Abbreviations

Substrate - the medium used to support plants in a hydroponic system, usually inert (providing physical support only, with no nutritional benefit)

Hydroponic nutrient formulations – generally supplied as two separate, concentrated components which both need to be diluted before use

Sequential nutrient system – at least two different nutrient formulations used at different stages of a crop's developmental cycle, formulated to meet differing nutritional requirements for vegetative growth (Growth formulation) and crop formation and development (Bloom formulation)

Non-sequential nutrient system – the same nutrient formulation system is used throughout the growth & production cycle of the crop

Electrical conductivity (EC) - a measure of ions in the solution; units = milliSiemens (mS)

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Executive Summary

What the report is about

This report details a short term project to evaluate the potential for hydroponic cranberry production in Australia. The project successfully demonstrated that cranberries can be grown hydroponically. However a number of potential constraints to commercialisation have been identified.

Who is the report targeted at?

An opportunity exists for growers and investors in the horticulture industry to develop and market fresh cranberries. They would make a welcome addition to Australian fresh berries, and would add to the growing demand for 'nutraceuticals' and functional foods. With increased production, processed and value-added products could be developed and potentially replace imported processed cranberry products.

Background

Cranberries have traditionally been grown in natural marshes and wetlands, many of them natural peat bogs, where the moisture and decaying organic matter create ideal growing conditions for these plants. The high capital costs, combined with environmental concerns and limitations, would preclude traditional cranberry production in Australia; however cranberries are likely to be ideally suited to hydroponics.

Aims/objectives

The objectives of this project were to evaluate the effectiveness of one of the main commercial fruit and vegetable hydroponic production systems compared to a modified system to produce cranberries; to determine optimum nutrient, pH and management conditions, and to provide an indicative cost of the optimum system.

Methods used

Well known commercial hydroponic systems and techniques were trialled and modified, and crop management strategies were investigated on cranberry plants grown in hydroponics. The hydroponic systems used in this project were set up in a protected outdoor environment, which substantially reduced the otherwise high capital costs of production.

Results/key findings

This project has evaluated a number of commercial hydroponic systems and determined a modified optimum hydroponic system for cranberry production. The key findings are:

- Choice of appropriate geographical locations providing moderate summers, adequate rainfall and sufficient chilling hours over the dormant winter period would allow open-air set-up and minimise set-up costs and overheads

- A recirculating system is essential, with adequate humidity in the micro-climate surrounding the plants, either through incorporation of a misting system or selection of appropriate geographical locations

- Acidic conditions with pH below 6.0, preferably in the range pH 4.0 – 6.0. This is facilitated by choice of acidic medium, ideally a combination of peat mixed with a coarser medium such as coconut fibre

- Use of a non-sequential nutrient mix, EC ~1.5-2.0 mS

- Minimisation of transplantation & disturbance of root mass
- Raised troughs/beds to allow canopy growth, maximise yield and minimise harvest costs
- Light shade (< 25%), with ambient temperatures not exceeding 34°C for prolonged periods in the absence of sufficient cooling
- Some protection from pests and hail (open mesh) may be necessary while still allowing for open-air pollination by bees. Manual control and removal of pests in a completely open set up is not likely to be possible or cost-effective on a large scale

Implications for relevant stakeholders in the horticulture industry:

The 16 month production cycle from flower bud formation to harvest of fruit, means that management practices or seasonal influences in any year have an impact on crop production for the following year.

A suitable environment is essential for hydroponic cranberry production. It is unlikely to be cost-effective in dry or hot climates with low rainfall over the growing season or in areas with low chill hours as it would likely be too expensive to create a suitable climate-controlled environment. The draft indicative cost model, while subject to a number of factors not adequately determined in this project, includes some costs which could be significantly reduced or eliminated by not having to enclose the production in an artificial environment. Choice of a suitable geographical location which meets the optimum climatic conditions is likely to be the major limiting factor in assessing potential viability of a profitable venture.

Recommendations for Growers and Investors

Choice of location is critical to minimise cost of production. The location should have a climate of summer temperatures not generally exceeding 30-35°C, moderate rainfall or relative humidity throughout the growing season, and sufficient chilling hours during the dormant season.

A medium term pilot production trial would need to run over 5-8 years in a suitable location, due to the 16 month crop production cycle. Suitable planting material and an establishment phase to bulk up the material would be required. Choice of varieties with high yield and the ability to grow and fruit with a vertical growth habit would be beneficial. Variety development trials could be further investigated to extend the production window, increase yield and look at manipulation of sugars, flavours and active compounds.

Introduction

Cranberries (*Vaccinium macrocarpum*) have proven health benefits in the urinary tract, cardiac and oral health areas, and have documented anti-cancer and anti-ulcer properties. To date, no synthetic substitute for Cranberry has been developed and with the rise in consumer awareness of the benefits of including functional foods in the diet to improve and maintain wellness, the medicinal properties of cranberries create an opportunity in Australia to produce and market fresh cranberries in an environmentally sustainable manner to meet the demand for fresh functional foods.

Cranberries have traditionally been grown in natural marshes and wetlands, many of them natural peat bogs, where the moisture and decaying organic matter create ideal growing conditions for these plants. They thrive in conditions more acidic and wet than most fruit crops could tolerate. Large scale production occurs in natural and artificially created wetlands in temperate climate zones of the northern USA, Canada and Chile, and a number of Northern hemisphere countries. The high capital costs for cranberry bog construction and planting and the specialised harvesting equipment, combined with environmental concerns and limitations would preclude traditional cranberry production in Australia, however cranberries are likely to be ideally suited to hydroponics. The US commercial variety “Bergman” is in cultivation in Australia and available through nurseries, so accessing suitable planting material for this size project was not an issue.

Cranberry plants are perennial, low-growing woody vines, which develop long trailing stems or runners up to 2 metres in length that intertwine and form a clumping mat when grown in traditional or cultivated wetland environments. Short vertical branches (uprights) develop from buds along the length of the runners, and these uprights, which have a vertical, non-trailing growth habit and tend to be less than 20cm in length, are where the terminal buds containing the flower buds are formed. Most of the flowers and thus berries are formed on these uprights, so production fields are flooded to aid harvest, as the ripe berries float.

Although cranberry fields are flooded during harvest and during winter dormancy to protect the plants from snow and ice damage, and occasionally for pest control, good soil drainage is also necessary, particularly through the growing season; cranberries will not produce well in permanent flood conditions. In commercial production, a layer of sand may be added every few years, resulting in alternating layers of rich, rotting organic matter, and sand. The soil is never cultivated once planted, so a core soil sample from a long standing commercial field will reveal these distinct layers. The sand added to the ice in winter is believed to encourage new growth, and may assist with pest control.

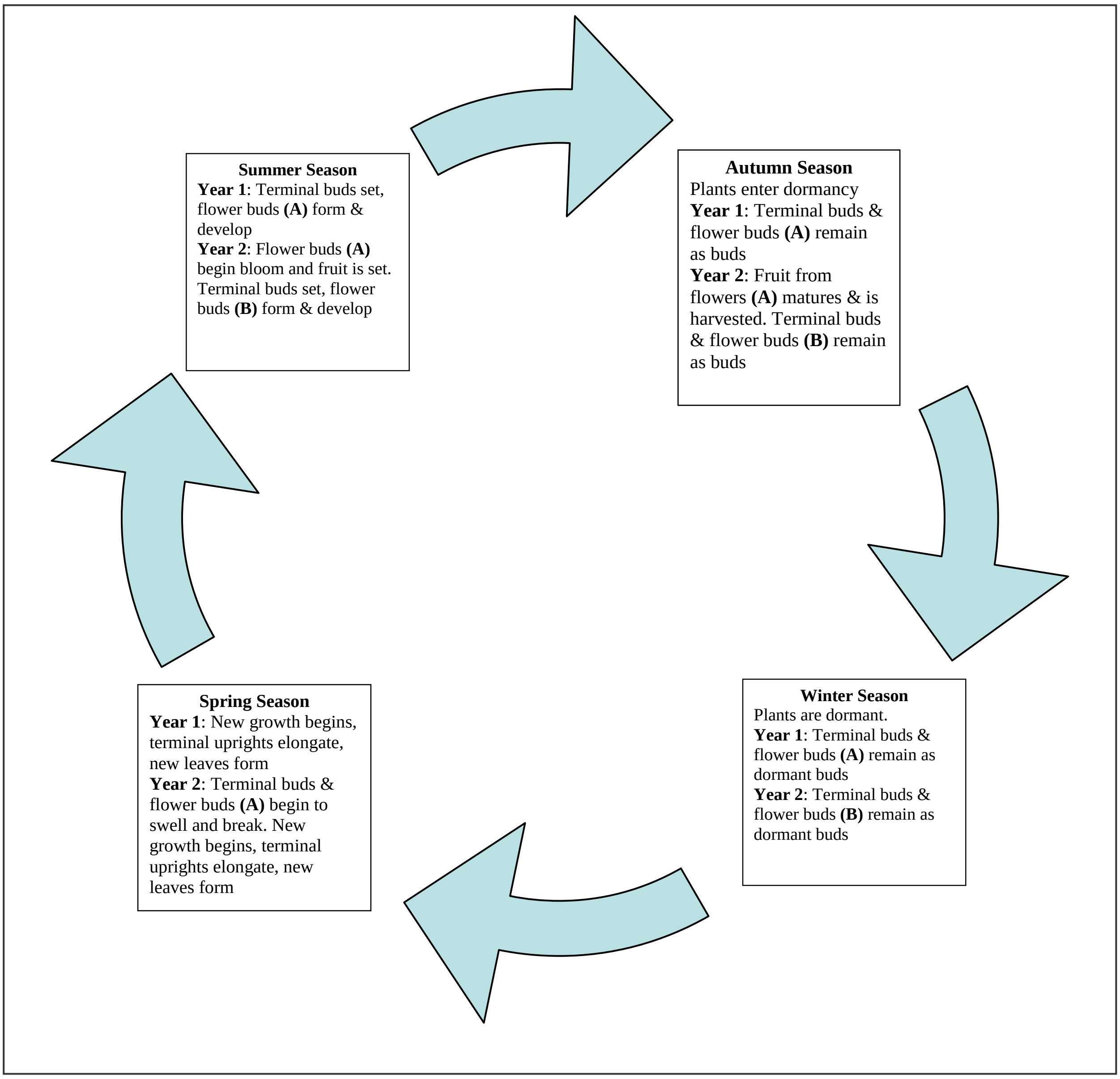


Figure 3: Cranberry flower and fruit production cycle

(Bioden Pty Ltd 2008)

Cranberry fruit production is a 16 month cycle, where the flower bud set occurs a full year before it opens and sets fruit, which then matures some 80 days after fruit set. The terminal buds on uprights are initiated in mid-summer of the year before the crop forms, and the flower buds are formed within these terminal buds. The buds continue to develop into autumn, then the whole plant becomes dormant until the following spring, when the buds swell and break as plant dormancy breaks, and the flowers bloom and fruit is set through open-pollination by bees in summer. From mid-summer to mid-autumn, the cycle overlaps, as new terminal buds and flower buds are developing while the fruit is setting, growing and ripening.

Plant dormancy is triggered by a combination of short day length and low temperatures, and broken by the reverse (increasing temperatures and day length). Cranberry plants require sufficient chilling hours (below approx. 8^oC), as with many other perennial fruit crops, in order to break dormancy and initiate flowering. The characteristic color develops as the fruit matures in early/mid-autumn.

Objectives

The project aimed to identify the hydroponic system that would be most suitable for cranberry production, identify crop management strategies and provide an indicative cost of the system. Fresh cranberries could make a welcome addition to Australian fresh berries and would mature at a time when there are not many fresh berries available on the market. The medicinal properties of cranberries create an exceptional opportunity to establish a large industry in Australia for domestic sales. With increased production, processed and value-added products could be developed and potentially replace imported processed cranberry products.

Methodology

Hydroponic system

Initial trials were set up to evaluate the most common systems used for commercial hydroponic fruit & vegetable production, and bioassays were established to evaluate and determine the optimum requirements for four growing conditions which can be varied in a hydroponic set-up: substrate, pH range, shade and nutrition

Hydroponic systems

The hydroponic systems evaluated were:

1. Drip feed/continuous system (C): plants were maintained in pots filled with substrate and nutrient solution was provided continuously via drippers above the substrate surface, which flowed over the plant and roots and was collected and recirculated on a continuous basis. The pots were enclosed in hydroponic troughs set up for collection and recirculation which maintained a low level, continuous film of nutrient solution (less than 2 cm deep), ensuring the substrate did not dry out.

2. Sump system (S): plants were in pots which sat in a trough of nutrient solution, to simulate the traditional cranberry marsh/bog environment. The nutrient solution was fed directly into the sump, and recirculated. Sump level was set and maintained at approximately 5cm deep. This level of saturation more closely mimics the natural growing conditions of cranberries, where they sit in water-logged soil for much of the year.

Both systems were connected to the same recirculating system with one reservoir of nutrient solution. There were 20 replicates in each system, with each system in 4 sets of 5 plants per trough, and the troughs (sets) were alternated (see Photo 1) i.e. S1, C1, S2, C2, etc. This ensured that conditions such as nutrient levels, temperature and pH were identical, and the same size drippers and outlets were used so that the rate of flow through each trough remained constant. The main difference in the two systems was how and where the nutrient solution was delivered to the plants (above the substrate surface or into the pool of liquid), and how much moisture surrounded the roots.

The commercial systems consisted of hard PVC troughs with solid lids and end caps. Holes were cut in the lids to accommodate the pots, and drain plugs were placed at different heights in the end caps to either drain continually or provide a permanent sump of nutrient solution. The troughs sat on a raised metal bench (elevated to approximately 1.2 m high), with a wide mesh/grill top to allow the plants to trail down over the edges of the pots and troughs, without becoming too entangled with each other.

The solid lids on the troughs were used to minimise both evaporation and the amount of algae collecting in the hydroponics system, although the top of the substrate (rockwool) in each pot had green algae growing on it. This did not appear to have had any effect on the growth of the cranberry plants, and was treated regularly with a standard commercial hydroponics treatment, hydrogen peroxide, added to the nutrient solutions.

Photo 1 gives an indication of the size of the cranberry plants at the start of the season 1 trials (October 2005). All plants used were cuttings sourced from the same supplier, and had 1-5 stems (main stems and runners), and no stem was longer than 25 cm. Photos 2 and 3 show plants from the hydroponic systems at the end of the first season; the plants grown in the Continuous system had more vigorous growth than those grown in the Sump system.

Figure 4: Hydroponics setup – Cranberry plants (October 2005)

(Bioden Pty Ltd 2008)

Figure 5: Plant from Continuous hydroponic system

Figure 6: Plants from Sump hydroponic

Growth (biomass of the plant) at the end of the growing season, as the plants entered dormancy, was measured in two ways:

- Number of stems, which refers to both runners and uprights, and gives an indication of the branching and vigour of the plants; and
- Total length of all of the stems (uprights, where most of the flowering occurs, are usually no more than 10-20cm in length, and runners may be several metres in length).

Standard conditions

The standard growing conditions (controls) in the first season were defined as:

- Substrate - rockwool (*Growool*® brand), which is a standard hydroponic substrate for many horticultural crops
- pH range of nutrition / treatment solution - 5.0-6.0, more acidic than for other plants, to match the cranberry's natural environment
- Shade level - full sun. (Where insect screening for plant protection was required, the mesh used had a shade rating of less than 10%)
- Nutrition – a commercial sequential hydroponics nutrient system was used initially (*Plantastic*® brand, suitable for use with rockwool substrate/medium). A sequential nutrient system is one which uses more than one nutrient formulation, usually a Growth formula for vegetative growth, followed by a flowering or "Bloom" formula to be applied at the appropriate time to trigger the plants to flower and/or fruit. Each formulation (both growth and bloom) consists of 2 separate concentrated parts (A & B) which need to be diluted with water immediately prior to use. The rate used was 2.5ml/L of each part, which gave an Electrical Conductivity (EC) of ~1.0 mS
- Water - Rainwater was used as the standard water for mixing the nutrient solutions and in the water only trials, as rainwater has virtually no minerals or salts, and cranberry plants are known to be sensitive to chlorine. Tap water also shows some electrical conductivity (EC: 0.30 – 0.50mS), compared to rainwater which has nil, and has a more significant pH buffering capacity than rainwater. Hydrogen peroxide, at recommended commercial rates was added to all solutions/treatments to treat and control green algae growth, and a UV filter was also incorporated into the recirculating system for microbial growth control.

The hydroponics systems were set up with plants potted into a standard commercial hydroponics substrate (rockwool), and with recirculating standard nutrient solution provided through adjustable drippers.

Bioassays

The bioassays were set up to evaluate four aspects of hydroponic growing conditions which can be varied to optimise crop management.

pH range

The bioassay to determine pH requirements was established as follows:

- pH range - 5.0-6.0 (Standard, control)
- raised pH range - above 6.0
- lowered pH range – below 5.0

There were five plants per treatment, and all other conditions (shade level, substrate and nutrient solutions) were kept standard as defined above.

Shade

The bioassay to determine shade requirements was established using the following shade treatments:

- Full sun (Standard, control)
- Polyhouse (~8% shade), small commercial polyhouse (~3mx4m)
- 50% shade cloth, which completely enclosed a mini shade house structure
- 70% shade cloth, which completely enclosed a mini shade house structure
- 90% shade cloth, which completely enclosed a mini shade house structure

There were five plants per treatment, and all other conditions (pH, substrate and nutrient solutions) were kept standard as defined above.

Nutrition

The bioassay to determine nutrition requirements was established using the following treatments:

- Standard nutrition - *see initial standards*,
(rate 2.5ml/L each of Parts A & B in rainwater; Standard, control)
- Standard nutrition, half strength
(rate 1.25ml/L each of Parts A & B in rainwater)
- Standard nutrition, double strength
(rate 5ml/L each of Parts A & B in rainwater)
- Standard nutrition, utilising tap water in place of rainwater
(rate 2.5ml/L each of Parts A & B in tap water)
- Standard nutrition, Growth formula only throughout trial (no sequential treatment)
(rate 2.5ml/L each of Parts A & B in rainwater)
- Standard nutrition, Bloom formula only throughout trial (no sequential treatment)
(rate 2.5ml/L each of Parts A & B in rainwater)

- Combined nutrition, (an alternative commercial, non sequential system, 2 parts combined as for standard, and used continually without regard for cropping season, *Superior Blend*® brand) (rate 2.5ml/L each of Parts A & B in rainwater)

- Combined nutrition, half strength (rate 1.25ml/L each of Parts A & B in rainwater)

- Combined nutrition, double strength (rate 5ml/L each of Parts A & B in rainwater)

- Rainwater only* (see substrate bioassay also)

There were five plants per treatment, and all other conditions (shade level, substrate and pH of treatment solutions used) were kept standard as defined above.

Substrate

The bioassay to determine optimum substrate was established using the following treatments:

- Rockwool, with standard nutrition (Standard, control)

- Coir Peat, with standard nutrition

- Peat (from sphagnum moss), with standard nutrition

- Acid mix (potting mix for acid loving plants), with standard nutrition

The substrate trials were also repeated using rainwater with no added nutrients:

- Rockwool, with rainwater only *

- Coir Peat, with rainwater only *

- Peat (from sphagnum moss), with rainwater only *

- Acid mix (potting mix for acid loving plants), with rainwater only *

There were five plants per treatment, and all other conditions (shade level, nutrition, {*except rainwater treatments}, and pH of treatment solutions used) were kept standard as defined above.

Modified hydroponic system

Cranberry plants were transplanted into a modified hydroponics system based on the results from the initial trials. Optimum pH, nutrient, and medium for cranberry growth were implemented, and the tagging system from the initial trials was maintained with the transplanted material, to track progress of plants from season to season, and determine any long term effects on vegetative growth or flowering.

The substrate chosen for the modified system was a blend of peat moss and coir peat, giving a resultant (optimum) pH of around 5, and a medium which stays moist without getting too waterlogged.

The nutrient solution chosen was the combined, non-sequential nutrient blend, adjusted to give an EC of approx 1.50 mS, diluted with rainwater, and adjusted to pH range 5.0 – 6.0.

Plants were set up in a modified hydroponic system, with 4 pots per tray, and trays placed on 2 metal poles 1.2 – 1.4 m above the ground, to allow the runners in the canopies to hang down the side of the pots, and grow at least 1m in length with minimal tangling. The entire set-up was enclosed in a structure covered with "hail mesh" – a white open-weave mesh designed to protect the plants from hail, and some pests, particularly locusts, while not unduly shading the plants to any significant degree (see Photos 4 to 7). The open-weave mesh size allowed bees to enter for pollination.

The Australian-made system chosen for the modified hydroponic system trials was modified to allow for recirculation of the nutrient solution, with a sump depth of approximately 2-3 cm above the base of the pots. The troughs/trays were moulded as one unit, so leakage and solution losses were minimised. The units were a standard, unique design with valves and wicks to allow liquid levels to fall to a thin film without drying, and refill only to maintain wick moisture. The modification for cranberries was necessary to allow for recirculation and a small sump, as a thin film only was not sufficient; the weight of a plant with a large trailing vegetative canopy can lift its pot sufficiently to break the film on one side. This minor lifting, even if incomplete (i.e. one side of the pot still in contact with the liquid) can cause the plant to die slowly (over days to weeks) even when the film/sump is re-established within several hours of it lifting. (See dead plant in foreground of Photo 4). Cranberries require adequate moisture at all times, particularly during active vegetative growth. The modification for recirculation also allowed for flushing of the system, as extremes of high temperature and low humidity caused salt build-up.

Figure 7: Modified hydroponics system set-up (prior to misting system installation).

Note the dead plant in foreground. **(Bioden Pty Ltd 2008)**

Figure 8: Hydroponic trays on raised open pole structure (overhead hanging misting head showing in background)

(Bioden Pty Ltd 2008)

Figure 9: Hydroponic trays set up (shadecloth just visible in top left corner)

Figure 10: Trailing habit of vines

A misting system needed to be set-up above the rows of trays, to attempt to offset the harsh effects of the drought, as humidity was extremely low and temperatures were quite high, for the majority of the growing season. The misting system was operated via a timer connected to the water pump and tank, and operated for 1-2 minutes every 20 to 60 minutes between 9am and 8pm on days where the temperature exceeded 34^{o}C. A flat overhead layer of shade cloth (~25% shade) was also set up ~0.5m above the trays, to reduce the direct overhead burning effect of sunlight, while still allowing plenty of light to reach the plants, and the misting heads were suspended above the rows of plants in the hydroponic trays. During 2007, water restrictions in the area were tightened further, and the misting system could not be used in the 2007/2008 growing season.

Flower bud formation timing trials

Trials were established to attempt to determine the timing window of flower-bud set, as the buds are set in the season before flowers appear, on the growing tips of the uprights. During the growth season, three sets of ten plants were given the following treatments:

Set 1: All tips (terminal buds) on the entire plant (runners and uprights) were pruned

Set 2: One main branch (loosely tagged with a cable tie near the base stem) had all of the tips on that branch (runners and uprights) pruned

Set 3: Each plant had all of its existing tips mapped for observation (i.e. the runners and uprights network was sketched/mapped, to determine which had flowers the following season, and if any shoots which appeared after mapping in the same season would flower the following season)

Micro climate gradient trial

A trial was established to measure the benefits of micro climates on vegetative growth. This was done by arranging cranberries on four benches with shading walls 1m from the cranberries on the south east and south west perimeters. This created conditions of morning shade on the south eastern edge and afternoon shade on the south western edge, with the southern corner receiving the most shade. It was intended that the partial shade would create gradients of micro climates of cooler and more humid conditions along the edges with the northern corner having the hottest and driest conditions.

Owing to limitations on plant numbers available, due to the two years needed to establish new plants, cranberries from the previous season were placed at random on the four benches. The use of these older plants in this trial needs to be taken into consideration when interpreting the results owing to the earlier observation that damage from one season continues to have a negative impact on growth in the following season; most notably evident from the transplanting results and inhibition of terminal bud development.

Once the cranberries went dormant in May, they were assessed for vegetative growth and rated on a scale of 1-4 for three measures of growth:

Number of main stems or runners alive
Cranberry plants may have one or more of their branches die off over the growing season for a number of reasons: physical damage (weight, pests, birds), disease, or stress (nutrition, water, temperature, etc). The plant may then continue to deteriorate and eventually die, maintain its growth with remaining live branches, or exhibit new growth. Over the growing season, dead branches, or those with dead tips, were pruned short (<25 cm), to give an indication of stress and growth over the season.

Scale used for number of stems alive:

1. 0 (plant was dead)

2. 1 only, of several (more than half the existing branches on the plant were dead)
3. 2-3 (more than half the existing branches on the plant were alive)
4. >3 (most or all of the plant was alive and growing)

Length of branches
Over the growing season, dead branches and tips of runners were pruned, so the overall lengths of the branches at the end of the season gives a reasonably accurate picture of the season's growth.

Scale used for length of branches:
1. all short (< 25 cm, pruned/snapped off)
2. 1-2 long (most runners short, but plant has a few long runners (> 70 cm)
3. medium length (majority of plant runners are 25 - 70 cm; likely only tips may have died)
1. many long (majority of plant runners > 70 cm)

Number of uprights
The uprights are where the terminal buds and flower buds are formed; large numbers are indicative of healthy, vigorous plants, low numbers (<20) generally reflect a stressed or dead/dying plant.

Scale used for number of uprights:
1. <10
2. 10-20
3. 20-50
4. >50

The average of each of the three measures of vegetative growth was then plotted to provide a visual map of any growth gradients.

Results and Key Findings

Hydroponic system results

The two hydroponics systems trialled in the first season showed a significant difference in growth rates of the cranberry plants in each system. Tables 1A and 1B show the stem number and lengths for the plants in each hydroponics system.

Table 1A: Number of Stems per plant: Hydroponics Trials

Replicate	**1**	**2**	**3**	**4**	**5**	***Average***
TREATMENT						
Hydroponics Trials						
Standard Nutrients: Continuous (Dripper) Set 1	71	129	111	79	49	***87.8***
Standard Nutrients: Continuous (Dripper) Set 2	188	111	138	157	136	***146***
Standard Nutrients: Continuous (Dripper) Set 3	137	146	158	98	167	***141.2***
Standard Nutrients: Continuous (Dripper) Set 4	94	99	128	102	211	***126.8***
Average: Continuous (Dripper)	***122.5***	***121.25***	***133.75***	***109***	***140.75***	***125.45***
Standard Nutrients: Sump Set 1	31	54	37	33	52	***41.4***
Standard Nutrients: Sump Set 2	67	35	50	51	38	***48.2***
Standard Nutrients: Sump Set 3	40	57	37	59	55	***49.6***
Standard Nutrients: Sump Set 4	63	51	58	42	54	***53.6***
Average: Sump	***50.25***	***49.25***	***45.5***	***46.25***	***49.75***	***48.2***

Table 1B: Length (cm) of Stems per plant: Hydroponics Trials

Replicate	1	2	3	4	5	*Average*
TREATMENT						
Hydroponics Trials						
Standard Nutrients: Continuous (Dripper) Set 1	2455	3855	3125	2575	1725	***2747***
Standard Nutrients: Continuous (Dripper) Set 2	4910	2485	4170	5605	4690	***4372***
Standard Nutrients: Continuous (Dripper) Set 3	4395	3520	4430	3510	5595	***4290***
Standard Nutrients: Continuous (Dripper) Set 4	2440	2925	2870	3010	8805	***4010***
Average: Continuous (Dripper)	***3550***	***3196.2***	***3648.7***	***3675***	***5203.7***	***3854.75***
Standard Nutrients: Sump Set 1	1205	1480	1595	965	2290	***1507***
Standard Nutrients: Sump Set 2	2375	1255	2030	1455	1490	***1721***
Standard Nutrients: Sump Set 3	1410	2065	1165	2545	2465	***1930***
Standard Nutrients: Sump Set 4	2525	1615	2200	1850	1990	***2036***
Average: Sump	***1878.7***	***1603.7***	***1747.5***	***1703.7***	***2058.7***	***1798.5***

Plants in the continuous, dripper system had more than twice the number of stems and total length of stems on average than the ones in the sump system. The only difference in growing conditions was the method of delivery of the nutrients, and reviews on the growing conditions of cranberries and related plants such as blueberries, suggest this may in part actually be due to the cooling effect from the nutrient solution applied above the surface via the drippers. It is also likely the location of the drippers provided a micro climate of higher relative humidity. In hot conditions, when temperatures exceed ~ 32^{o}C, it can be beneficial for these types of plants to either flood (traditional cranberry beds) or mist the plants to prevent heat damage. As Australian summer conditions are often hot and have little or no rainfall in many regions, this is an important consideration. The root mass was smaller on the sump plants, as the roots did not extend into the permanent wet zone, indicating a preference for moist, not wet conditions.

The drippers used in the initial hydroponics systems were problematic, as algae growth (which occurs in hydroponics where the system is exposed to light), and the nutrient salts both caused blockage of the drippers, and they had to be frequently unblocked and reset. This would not be practical on a commercial scale.

The purchased commercial systems proved to be quite difficult to make watertight at all the joins, and whilst the leaks at the end caps and drain plugs were minimised, leaks in the recirculating system would not be acceptable on a commercial scale. Alternative systems were implemented and modified to determine a more suitable system for commercialisation, as the solution loss on a larger scale set up would be more significant.

The rockwool substrate was initially quite alkaline, so it had to be acidified before planting. Use of a recirculating hydroponics solution allows manipulation of the pH to more suitable growing conditions, usually over a relatively short time and acidification of the substrate prior to planting should be carried out for hydroponic cranberries.

Bioassay results

pH bioassays

Tables 2A and 2B show the stem number and lengths for the plants in the pH trials. As expected, plants with a lower pH tended to grow better, both in terms of the number and length of stems. The pH ranges in this trial refers to those of the nutrient solutions actually added to the plants in each bioassay.

Table 2A: Number of Stems per plant: pH Trials

Replicate	**1**	**2**	**3**	**4**	**5**	***Average***
TREATMENT						
pH Trials						
Standard Nutrients: pH standard	15	9	7	25	6	***12.4***
Standard Nutrients: pH Raised (more alkaline)	17	23	21	14	9	***16.8***
Standard Nutrients: pH Lowered (more acidic)	27	49	27	15	9	***25.4***

Table 2B: Length (cm) of Stems per plant: pH Trials

Replicate	**1**	**2**	**3**	**4**	**5**	***Average***
TREATMENT						
pH Trials						
Standard Nutrients: pH standard	195	245	155	245	80	***184***
Standard Nutrients: pH Raised (more alkaline)	305	245	195	150	125	***204***
Standard Nutrients: pH Lowered (more acidic)	475	485	355	155	95	***313***

The rockwool (*Growool*®) used as the standard growing substrate for the majority of the plants in the trials was initially alkaline, and even with acidification prior to planting, the pH of the solutions surrounding the bioassay pots was initially higher than that of the solutions added for each treatment. It was much more difficult to achieve and maintain the desired pH range for the plants in the bioassays, as they were set up in sump style hydroponics conditions, with no recirculation. The algae also had an effect on pH and nutrient availability for the plants in the bioassays. The pH ranges selected for the pH trials (lowered pH < 5, standard pH 5-6, raised pH >6) and used for nutrient solutions added, were not able to be maintained in the actual growing conditions. The pH of both the standard and raised pH replicates were not significantly different as measured in actual pot conditions, and thus the standard pH conditions achieved were more alkaline than desired. This was also true for the pH conditions of all of the other Controls (Standard pH and Nutrients in *Growool*®) in the bioassays. This trial therefore illustrates a trend for better growth with lower pH, as expected, and the difficulties encountered using *Growool*® as a substrate, particularly in a non-recirculating system.

Maintaining narrow pH ranges was also difficult due to the complete lack of buffering capacity of rainwater.

Substrate bioassays

The substrate trials were to determine the most suitable planting medium or substrate for cranberry plants. Tables 3A and 3B illustrate the obvious differences in growth using different substrates, and a simple nutrient trial was done as a sub trial within this one (with/without standard nutrients). The pH of the solutions/rainwater added to the trials was as defined earlier, but actual pH measured in the solutions surrounding each trial varied widely with the type of substrate.

Table 3A: Number of Stems per plant: Substrate Trials

Replicate	1	2	3	4	5	*Average*
TREATMENT						
Medium Trials						
Standard Nutrients: Peat Moss	72	71	73	48	42	***61.2***
Standard Nutrients: Coir Peat	45	97	46	37	52	***55.4***
Standard Nutrients: Acid Mixture	20	24	29	21	24	***23.6***
Standard Nutrients: *Growool®*	16	10	12	12	17	***13.4***
Rainwater only: Peat Moss	8	36	15	14	48	***24.2***
Rainwater only: Coir Peat	6	4	4	6	4	***4.8***
Rainwater only: Acid Mixture	9	2	2	8	2	***4.6***
Rainwater only: *Growool®*	10	18	13	11	17	***13.8***

Table 3B: Length (cm) of Stems per plant: Substrate Trials

Replicate	1	2	3	4	5	*Average*
TREATMENT						
Medium Trials						
Standard Nutrients: Peat Moss	2250	2565	2405	1840	1860	***2184***
Standard Nutrients: Coir Peat	1185	1885	1830	1305	1910	***1623***
Standard Nutrients: Acid Mixture	550	630	725	625	530	***612***
Standard Nutrients: *Growool®*	190	190	230	170	325	***221***
Rainwater only: Peat Moss	480	640	715	850	940	***725***
Rainwater only: Coir Peat	210	90	100	190	50	***128***
Rainwater only: Acid Mixture	265	40	130	110	110	***131***
Rainwater only: *Growool®*	190	280	175	245	335	***245***

Peat moss was clearly the best substrate for cranberry plants of those trialled, and this was most likely due to its low pH (measured pH growing conditions averaged around pH 4 for the entire trial, regardless of pH of the solution added). This is supported by the fact that the plants with rainwater only and no nutrients grew better in the peat moss substrate than any of the other substrates. The peat moss used was very fine and stayed moist for longer than the other substrates, but some of the plants lost low level branches (branches near the base of the main stem), possibly due to rot. This suggested some other material should be included to reduce the waterlogging effects.

Plants in coir peat had similar good growth with added nutrients, but performed very poorly in rainwater alone, showing a lack of available nutrients from the substrate. Coir peat also showed hydrophobic tendencies in the trials (difficult to rewet if it dried out). Coir peat contains tannins, and these were released and stained the surrounding solution, but did not seem to have affected growth.

The acid mix and coir peat substrates both did not appear to support or encourage green algae growth, which may bear further investigation.

Nutrient bioassays

The standard nutrients used were: (1) a standard sequential hydroponic treatment (Standard Nutrients) consisting of a Growth formula for vegetative growth, and a Bloom formula for use during flowering, and (2) a non-sequential hydroponic treatment (Combined Nutrients). The nutrient trials compared various strengths of both the non-sequential and sequential treatments, and use of only one of the two sequential formulations (Growth or Bloom only). Tables 4A and 4B give the biomass data for the various nutrient combinations trialled.

Table 4A: Number of Stems per plant: Nutrient Trials

Replicate	**1**	**2**	**3**	**4**	**5**	***Average***
TREATMENT						
Nutrient Trials						
Combined Nutrients: Half Strength	31	25	25	12	19	***22.4***
Combined Nutrients: Normal Strength	36	38	31	26	8	***27.8***
Combined Nutrients: Double Strength	20	35	16	7	21	***19.8***
Standard Nutrients: Half Strength	21	18	10	10	8	***13.4***
Standard Nutrients: Normal Strength	28	23	9	19	24	***20.6***
Standard Nutrients: Double Strength	46	24	27	24	28	***29.8***
Standard Nutrients: Growth Formula Only	27	24	11	17	12	***18.2***
Standard Nutrients: Flower Formula Only	25	17	30	6	6	***16.8***
Standard Nutrients: Made with Tap Water	25	21	20	22	23	***22.2***

Table 4B: Length (cm) of Stems per plant: Nutrient Trials

Replicate	1	2	3	4	5	*Average*
TREATMENT						
Nutrient Trials						
Combined Nutrients: Half Strength	795	775	845	490	505	***682***
Combined Nutrients: Normal Strength	1440	1440	1235	1010	220	***1069***
Combined Nutrients: Double Strength	200	555	300	75	275	***281***
Standard Nutrients: Half Strength	505	280	300	240	230	***311***
Standard Nutrients: Normal Strength	240	295	85	135	280	***207***
Standard Nutrients: Double Strength	620	250	415	570	340	***439***
Standard Nutrients: Growth Formula Only	425	400	295	255	340	***343***
Standard Nutrients: Flower Formula Only	215	185	330	40	100	***174***
Standard Nutrients: Made with Tap Water	585	335	320	340	555	***427***

The non-sequential nutrient mix (Combined Nutrients) showed better growth, particularly early in the season, before problems with algae, pH and temperature had stronger effects on the plant health and growth. The Electrical conductivity (EC) was higher (~1.5 mS) with the Combined Nutrients formulation, using the same dilution rate as for the sequential, standard formula (equivalent rates, as per manufacturer's recommended rates). This could be reflected in the assumption that a non-sequential system must have all of the additional nutrients for flowering and fruit production present in the formulation, although the Standard Bloom formulation did not have a higher EC than its Growth formulation counterpart. The tap water used also showed some electrical conductivity (EC 0.30 – 0.50mS), (compared to rainwater which has an EC of zero), and had a more significant pH buffering capacity than rainwater. Although cranberries are reported to be sensitive to chlorine, the levels in the tap water used did not have any discernible effects in this trial.

The combined, non-sequential nutrient formulation at recommended rates was chosen for the modified hydroponic system based on the increased vegetative growth compared to the other nutrient combinations trialled. Due to the non-recirculating nature of the bioassay set up, there was significant growth of algae in the bioassay trial solutions. This, combined with temperature effects from the summer conditions on the relatively small volumes, had a strong effect on growth patterns. These external effects were "imposed" on all of the bioassays to the same extent, so the comparisons between treatments within the bioassays are still valid. The magnitude of these effects on growth patterns can be seen when comparing growth of the plants with "Standard" conditions in the bioassays with those in the larger, recirculating hydroponics systems.

Shade bioassays

The shade treatments imposed on the plants in each of the trials were in all directions, so all direct and incident and reflected light was reduced. Rated shade cloths were wrapped around each structure enclosing the trial plants, and only opened on one side when necessary for recording and maintenance purposes. Plants in the polyhouse also some light transmission reduction (on all sides) by the film enclosing the polyhouse, but the structure was much larger in size, and the ventilation was different. Tables 5A and 5B show the effects of various shade levels on growth rate.

Table 5A: Number of Stems per plant: Shade Trials

Replicate	**1**	**2**	**3**	**4**	**5**	***Average***
TREATMENT						
Shade Trials						
Standard Nutrients: Polyhouse	23	12	19	18	17	***17.8***
Standard Nutrients: 50% Shade	7	5	9	12	6	***7.8***
Standard Nutrients: 70% Shade	6	9	9	13	10	***9.4***
Standard Nutrients: 90% Shade	3	2	6	3	10	***4.8***
Standard Nutrients: Full Sun	27	16	17	10	11	***16.2***

Table 5B: Length (cm) of Stems per plant: Shade Trials

Replicate	**1**	**2**	**3**	**4**	**5**	***Average***
TREATMENT						
Shade Trials						
Standard Nutrients: Polyhouse	485	220	315	160	215	***279***
Standard Nutrients: 50% Shade	275	155	295	160	210	***219***
Standard Nutrients: 70% Shade	140	185	255	245	70	***179***
Standard Nutrients: 90% Shade	75	40	150	75	140	***96***
Standard Nutrients: Full Sun	405	230	265	260	155	***263***

The shade trials established that any more than light shade has a detrimental effect on cranberry plant growth. Some of this effect may have been due to air temperature effects: the polyhouse (shade <25%) and mini shade houses all had higher air temperatures than ambient for most of the day. This is in part due to less air movement, although this could have some beneficial micro climate effects on humidity.

It is interesting to note there was more of an effect on number of stems than total length, between most of the shade treatments. This was a reflection of the lack of development of uprights, which are necessary for flower and fruit formation, as the flower buds form each year in the terminal buds of the uprights.

In addition to decreased growth, the color of the plants was affected: the characteristic red appearance of the tips of the cranberry runners as they grew, was absent at 70% shade and higher, and the leaves on the plants grown in 90% shade were very small and dark in color. Algae growth was less of an issue at 90% shade, but the plant growth was hampered by lack of sunlight.

The plants in the polyhouse benefited from warmer temperatures early in the growing season, with increased growth compared to the others in the shade trial, including full sun, but the effects of higher temperatures and increased growth of algae caused significant problems during the warmer months.

Bioassay controls

Controls were replicated in each of the trials, and Tables 6A and 6B show there were not significant growth differences between them.

Table 6A: Number of Stems per plant: Controls

Replicate	1	2	3	4	5	*Average*
TREATMENT						
Standard Nutrients: Normal Strength [Table 4]	28	23	9	19	24	***20.6***
Standard Nutrients: Growth Formula Only [Table 4]	27	24	11	17	12	***18.2***
Standard Nutrients: pH standard [Table 2]	15	9	7	25	6	***12.4***
Standard Nutrients: *Growool*® [Table 3]	16	10	12	12	17	***13.4***
Standard Nutrients: Full Sun [Table 5]	27	16	17	10	11	***16.2***
Controls Average:	***22.6***	***16.4***	***11.2***	***16.6***	***14***	***16.16***

Table 6B: Length (cm) of Stems per plant: Controls

Replicate	1	2	3	4	5	*Average*
TREATMENT						
Standard Nutrients: Normal Strength [Table 4]	240	295	85	135	280	***207***
Standard Nutrients: Growth Formula Only [Table 4]	425	400	295	255	340	***343***
Standard Nutrients: pH standard [Table 2]	195	245	155	245	80	***184***
Standard Nutrients: *Growool*® [Table 3]	190	190	230	170	325	***221***
Standard Nutrients: Full Sun [Table 5]	405	230	265	260	155	***263***
Controls Average:	***291***	***272***	***206***	***213***	***236***	***243.6***

Modified hydroponic system results

Cranberry plants were transplanted into a modified hydroponics system based on the results from the first season's trials. Optimum pH, substrate and nutrient for cranberry growth were implemented (recirculating system with pH in the range 4.0 – 6.0, growing medium of 50% peat/50% coconut fibre and a non-sequential nutrient mix with EC ~1.5-2.0 mS), and the tagging system from the first season's trials was maintained with the transplanted material, to track progress and determine long term effects on growth and yield from the marked differences noted. The system was modified to assist flushing and remove excessive salt, and a misting system was installed.

The modified system set up was chosen taking into consideration specific crop management factors and the need to achieve optimum sustainability and minimise water consumption and loss. Some protection from pests and elements was required without excessive shade features, and allowing for natural pollination (bees). Where possible, support for Australian industries was also an influence.

The nutrient solution chosen was the combined, non-sequential nutrient blend for a number of reasons:

- bioassay results showed better results compared to the sequential system used initially
- it was manufactured in Victoria (although the company was bought out by a larger Hydroponics supplier during the project's life, so it hasn't been established if this will continue long term)
- the potential exists, with a local manufacturer, for development of an optimum blend of nutrients suited specifically to cranberries, and further nutrient trials may be possible as a separate, ongoing project
- flower bud formation occurs in the previous season's active growth, and under local conditions here, flowering, pollination and subsequent fruit set begin within 6 weeks of dormancy breaking. Therefore, as there are not highly distinct periods of vegetative growth separate from flowering, or bud formation for the next year's flowers, the need for a sequential nutrition system is less apparent than for other horticultural crops. The need for additional specific nutrients for the 3 week period immediately following fruit set may be investigated, but falls outside the size and scope of this project.

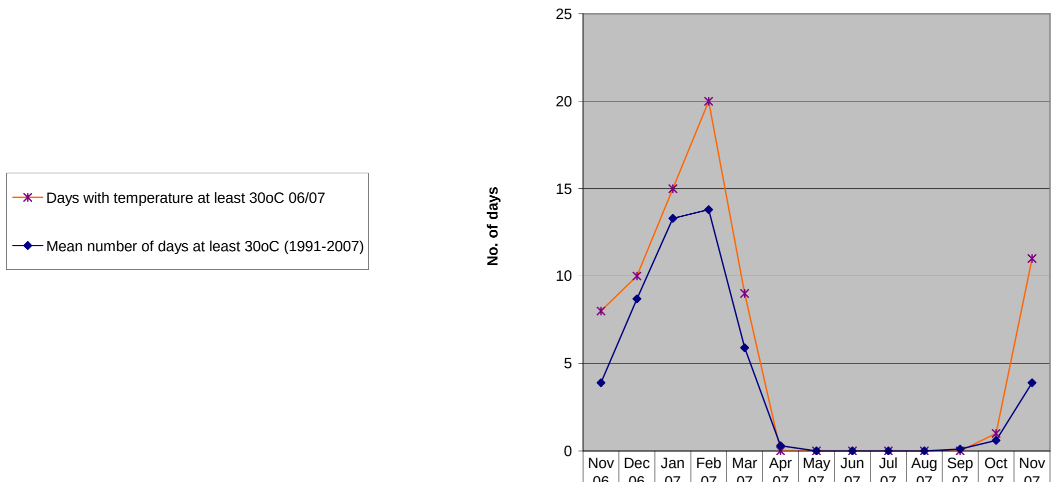
Following transplantation into the new system using the optimum substrate, some of the plants suffered from transplantation shock, particularly the plants with the largest canopy (the most vigorous growth), as they had the largest root mass, and it was difficult to extract the *Growool®* substrate (used in the first season) from the roots without disturbing them too much. This resulted in some complete plant deaths, and a number of deaths to one or more main branches of a number of plants, such that the canopy size of many of the plants was reduced.

The drought had a major impact on the growing conditions for the remainder of the project, despite the fact that the plants were growing in a liquid nutrient mix, and should have had sufficient water to cope with the extremely dry conditions.

Very low rainfall, combined with high temperatures and less cloud cover, caused the water loss from plants (through the leaves) to exceed that taken up by the roots, which resulted in stress and dehydration. In addition, the excessive evaporation of liquid from the surface of the growing medium caused a salt build-up. This would normally be flushed during rainfall, but the lack of rainfall combined with low humidity and high temperature caused a nutrient/salt build up around the plants, adding to the general drought stresses. Misting was instituted to provide some localised effects of increasing humidity, and reducing temperature, but the open nature of the set-up did not allow sufficiently different conditions from prevailing ambient conditions to have a marked effect.

Weather data for the 06/07 growing season shows that there were more days of at least 30^{o}C than average (see Figure 3), and that the rainfall was well below the long-term average. (see Figure 4). The growing season runs from about September to around April/May, and the 07/08 season also showed a dryer than normal pattern, despite significant rainfall in other parts of the country.

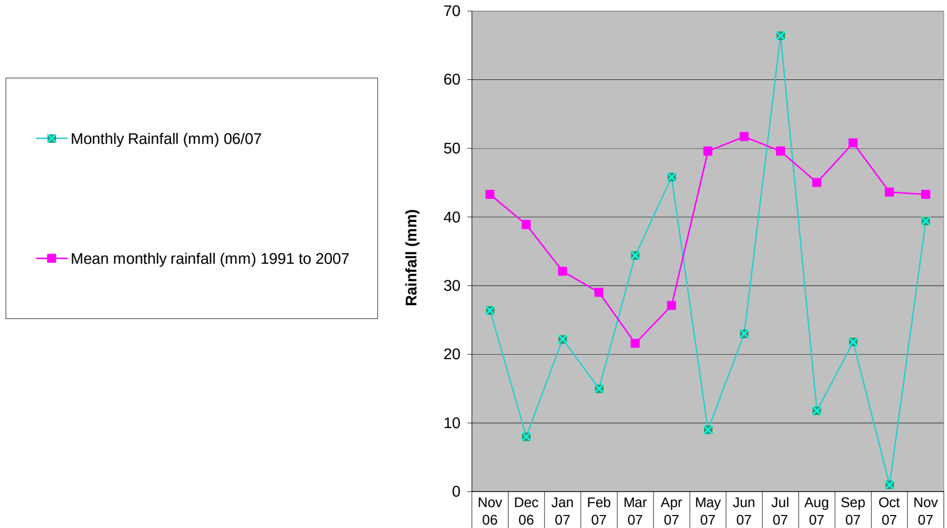
Number of days exceeding 30°C 06/07 season vs 16 year average (1991-2007)



	Nov 06	Dec 06	Jan 07	Feb 07	Mar 07	Apr 07	May 07	Jun 07	Jul 07	Aug 07	Sep 07	Oct 07	Nov 07
Days with temperature at least 30oC 06/07	8	10	15	20	9	0	0	0	0	0	0	1	11
Mean number of days at least 30oC (1991-2007)	3.9	8.7	13.3	13.8	5.9	0.3	0	0	0	0	0.1	0.6	3.9

Figure 11: 06/07 Season - Days of at least 30°C compared to long term average, for Bendigo

Average Rainfall 06/07 season vs 16 year average (1991-2007)



	Nov 06	Dec 06	Jan 07	Feb 07	Mar 07	Apr 07	May 07	Jun 07	Jul 07	Aug 07	Sep 07	Oct 07	Nov 07
Monthly Rainfall (mm) 06/07	26.4	8.00	22.20	15.00	34.40	45.80	9.00	23.00	66.40	11.80	21.80	1.00	39.40
Mean monthly rainfall (mm) 1991 to 2007	43.3	38.9	32.1	29	21.6	27.1	49.6	51.7	49.6	45	50.8	43.6	43.3

Figure 12: 06/07 Season - Rainfall (mm) compared to long-term average, for Bendigo

It is apparent that the climate in this region is not particularly suitable for open-air growing, and hydroponic production here would require a closed (climate-controlled) system, which is likely to be too cost-prohibitive. A draft indicative cost model has been estimated using information from this project and based on other estimates from industry costs & standards for similar crops, but three major variables: yield, harvest cost and farm gate price could not be adequately determined in this project. These factors would need to be more accurately determined to accurately predict the likely cost model and profitability. It is unlikely a closed system would be cost-effective, but this could be more accurately determined if trials in a more suitable climate could determine some of the unknown variables.

Indicative costs

Hydroponic Cranberry Draft Cost Model									
This budget assumes that cranberries are grown in a greenhouse that is solely for hydroponic cranberries.									
Assumes cuttings ordered and potted up in the year prior to the commencement of this model.									
Assumes cranberries planted at 4/m^2									
It should be noted that there would be no yield during the establishment years.									
	Data in yellow cells can be changed								
Assumptions			**Gross yield* kg/m^2**						
Greenhouse size	1	000m^2	0	0.25	0.5	1	2	3	4
		Gross yield (kg)	0	250	500	1,000	2,000	3,000	4,000
Net yield (kg)	90.0%	Premium	0	225	450	900	1,800	2,700	3,600
Farm gate value**	$25.00	/kg	$0	$5,625	$11,250	$22,500	$45,000	$67,500	$90,000
Variable Costs									
Land rent	$500.00	/1,000m^2	$500	$500	$500	$500	$500	$500	$500
R&M	$1,000.00	/1,000m^2	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
Nutrients & Sprays	$1,000.00	/1,000m^2	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
Electricity	$1,200.00	/1,000m^2	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200
Harvesting***	$5.00	/kg Gross	$0	$1,250	$2,500	$5,000	$10,000	$15,000	$20,000
Grading/Packing	$1.00	/kg Net	$0	$225	$450	$900	$1,800	$2,700	$3,600
Packaging	$1.00	/kg Net	$0	$225	$450	$900	$1,800	$2,700	$3,600
		Total	$3,700	$5,400	$7,100	$10,500	$17,300	$24,100	$30,900
Gross Margin			-$3,700	$225	$4,150	$12,000	$27,700	$43,400	$59,100
Overheads	$1,000.00	/1,000m^2	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
Depreciation	15	years	$6,433	$6,433	$6,433	$6,433	$6,433	$6,433	$6,433
Permanent staff	$17,500.00	/1,000m^2(0.25 F	$17,500	$17,500	$17,500	$17,500	$17,500	$17,500	$17,500
Net Margin			-$28,633	-$24,708	-$20,783	-$12,933	$2,767	$18,467	$34,167
ROI			-29.67%	-25.60%	-21.54%	-13.40%	2.87%	19.14%	35.41%
Capital Costs									
Greenhouse		$45,000	/1,000m^2						
Support system		$10,000	/1,000m^2						
Hydroponic system		$10,000	/1,000m^2						
Spray/misting system		$5,000	/1,000m^2						
Cooling system		$16,000	/1,000m^2						
Planting material		$8,000	/1,000m^2						
Packing shed		$1,000	/1,000m^2						
Cool Room		$1,500	/1,000m^2						
	Total	$96,500	/1,000m^2						
Important limitations regarding the assumptions used in this cost model:									
*Yield has not been established for hydroponic cranberry production									
**Farm gate price has not been established as there are no fresh cranberries available in Australia									
***Harvest cost has not been established for hydroponic cranberry production, but it is assumed that harvesting will be partially mechanized, possibly by shaking									
	Hand picking individual berries is anticipated to cost in the order of $20/kg								
	Harvesting cost/kg is expected to get lower as yield/m^2 increases due to expected harvesting efficiencies which are currently not taken into account in the model								
At this stage, no decision regarding potential commercial hydroponic cranberry production can be made given that three major variables: yield, harvest cost and farm gate price have not been adequately elucidated.									

Flower bud formation timing results

The results from the flower bud set formation timing were unable to be determined, as: only two plants from the entire system had flower buds, with one plant producing two flowers and the other plant producing only one flower. This was a result of the extreme drought stress placed on the plants (rather than the trial effects), such that terminal bud and flower bud formation were significantly impaired at a critical time. There was much less growth and elongation of uprights seen when plants broke dormancy, although terminal bud formation for uprights seems to have a wider window of time for formation. New buds can form over the growing season, throughout spring and summer, but the flower bud set either has a narrower window for formation, or is the first process sacrificed under less than ideal conditions. The misting system was either insufficient or implemented after the window for fruit bud set. The flowers produced did set fruit, indicating that the flower formation in the previous season is the more critical step, and if this occurs and flowers bloom, then fruit is probably likely to set, but there were insufficient numbers to state this with any certainty. The effects on terminal bud and upright formation during this same timeframe severely limited the subsequent growth and microclimate trials the following season.

Lack of sufficient chilling hours can be another possible cause of poor flower bud formation, but the climate here does and in fact did actually provide sufficient chilling hours, with many frosts over the dormant season, particularly during a dry winter. Photo 8 illustrates the cranberry plants covered with frost in 2006.

Figure 13: Cranberry plants covered in frost (Winter 2006)

(Bioden Pty Ltd 2008)

There was insufficient fruit set to attempt an analysis of cost of production by the end of the project term.

Micro climate gradient results

The distribution of vegetative growth appeared to be in a totally random manner with the micro climate gradients having no measurable impact at all. This was highlighted by comparing the expected result had the micro climates had a positive impact on vegetative growth, shown in Figure 6, with the actual results shown in Figure 5.

The lack of a positive result from this trial may be attributed to the micro climate gradient not being strong enough, but the results are likely to have been compromised by the need to use planting material from the previous season which may have brought forward too many growth limiting conditions from the previous season.

Although the micro climate gradients may have been strengthened had misting systems been included along the perimeters, at the time these trials were run it was not acceptable to run misting systems for an outdoor hydroponic production unit given the prevailing water crisis in Australia. It is unlikely that such a system would be cost effective even if it were allowed. This is a significant issue and forms part of the final recommendation to locate future cranberry production in a region with lower temperatures and higher humidity, and reasonable rainfall.

Actual distribution of vegetative growth ***NORTH↗***

4	1	4	2
3.3	1.3	2.6	3.3
1.3	2.3	2	3
1	1	1	4

2	3.6	4	1.6	2.6
2.6	3	1.6	1.6	1
2.2	1	3.6	1	1.3
3.6	4	3.6	2	1.6

4	2	3	3.3
2.6	2	2.3	1.6
4	2.3	1.6	1.3
4	1.3	1.3	1.6

3.3	2.3	3	3.6	4
3.6	2.6	3.3	1.6	4
3.3	2.6	3	3.3	1
4	1	3.3	1	3.3

Key

<2	Weak or no vegetative growth
2-3	Moderate vegetative growth
>3	Strong vegetative growth

Figure 14: Actual vegetative growth distribution diagrams from the micro climate gradient trial

Expected distribution of vegetative growth ***NORTH↗***

>3	>3	2-3	2-3
>3	>3	2-3	2-3
>3	>3	2-3	2-3
>3	>3	2-3	2-3

2-3	<2	<2	<2	<2
2-3	<2	<2	<2	<2
2-3	<2	<2	<2	<2
2-3	2-3	2-3	2-3	2-3

>3	>3	2-3	2-3
>3	>3	>3	2-3
>3	>3	>3	>3
>3	>3	>3	>3

2-3	2-3	2-3	2-3	2-3
2-3	2-3	2-3	2-3	2-3
>3	>3	>3	>3	>3
>3	>3	>3	>3	>3

Key

<2	Weak or no vegetative growth
2-3	Moderate vegetative growth
>3	Strong vegetative growth

Figure 15: Expected vegetative growth distribution diagrams from the micro climate gradient trial

Pests & Other Issues

Scale, caterpillars and spiders were the main pest issues encountered, and occasional green aphids. Pest control was generally physical removal of the pest, or occasional targeted application of simple pyrethroids. For a horticultural crop which is not native to Australia, and is not grown commercially, many opportunistic pests have found it a welcome host. Pest control will be an issue on a large scale in an open environment, as manual removal of pests is too labour intensive for large scale production, and this would be a major factor in any decisions regarding a possible commercial venture.

A plague of locusts threatened the crop during the first season, necessitating the construction of contained shelters which protected against large insect attack, but did not otherwise cause significant shade or temperature effects, or interfere with the trials. A severe hailstorm caused some damage to the plants, breaking off some of the larger, heavier branches. Preventing physical damage from ice and snow is one of the reasons commercial cranberry fields overseas are routinely flooded in winter.

Implications

Crop Management

The 16 month production cycle from flower bud formation to harvest of fruit, means that management practices or seasonal influences in any year will have an impact on crop production for the following year.

Location

A suitable environment is essential for hydroponic cranberry production. It is unlikely to be cost-effective in dry or hot climates with low rainfall over the growing season, as it would be too expensive to create a suitable climate-controlled environment. Similarly, a more suitable location would also have adequate chilling for cranberry flower bud and hence fruit formation to occur.

Recommendations

For Growers and Investors

Choice of location is critical to minimise cost of production. The location should have a climate of summer temperatures not generally exceeding 30-35°C, moderate rainfall or relative humidity throughout the growing season, and sufficient chilling hours during the dormant season.

A medium term pilot production trial would need to run over 5-8 years in a suitable location, due to the 16 month crop production cycle. Suitable planting material and an establishment phase to bulk up the material would be required. Choice of varieties with high yield and the ability to grow and fruit with a vertical growth habit would be beneficial. Variety development trials could be further investigated to extend the production window, increase yield and look at manipulation of sugars, flavours and active compounds.

Cranberry Production - The potential for using hydroponics -

by Christina Dennis

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This report details a short term project which evaluated the potential for hydroponic cranberry production in Australia. The project successfully demonstrated that cranberries can be grown hydroponically. However a number of potential constraints to commercialisation have been identified.

An opportunity exists for growers and investors in the horticulture industry to develop and market fresh cranberries. They would make a welcome addition to Australian fresh berries, and would add to the growing demand for 'nutraceuticals' and functional foods. With increased production, processed and value-added products could be developed and potentially replace imported processed cranberry products.

Cranberries have traditionally been grown in natural marshes and wetlands, many of them natural peat bogs, where the moisture and decaying organic matter create ideal growing conditions for these plants. The high capital costs, combined with environmental concerns and limitations, would preclude traditional cranberry production in Australia; however cranberries are likely to be ideally suited to hydroponics.

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