Final Report

Development of a new processed carrot industry

Tim Kimpton & Gordon Rogers
Applied Horticultural Research Pty Ltd

Project Number: VG06135

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Statement of Purpose:

This project was initiated as a collaboration between SDS Beverages, a commercial carrot (juice concentrate) processor, Excelfresh, a specialty seed subsidiary of the commercial seed company, South Pacific Seeds (SPS) and Applied Horticultural Research. The research aimed primarily to improve the agronomic understanding and management of black carrots to improve quality and yield for once over mechanical harvesting and subsequent processing into juice concentrate destined for health food drink and nutraceutical markets.

Funding

This project has been funded by Horticulture Australia Limited using voluntary contributions from SDS Beverages and Applied Horticultural Research and matched funds from the Federal Government.

Disclaimer:

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Important Note

The project partner and VC contributor SDS Beverages went into receivership in the last year of the project and has closed down operations since September 2009. This had significant financial impacts. The issue was brought to the attention of the HAL Project Manager in relevant milestone reports. The VC funds were paid by AHR in the final stages and this had a negative impact on the amount of funding available for the project. Despite this, AHR completed all the planned field research, analysis and reporting as planned.

The final report outlines clear recommendations on how to maximise yield and quality of black carrots and will be a valuable resource document with renewed interest in this fledgling industry.

Media Summary

Carrot juice production has for a long time been the lowest value sector in the Australian carrot industry. With global interest in functional foods, the availability of high anthocyanin lines, presents the industry with a real opportunity to regain some profitability.

Considerable difficulty in growing satisfactory commercial "black" carrot crops that are both acceptable to processors and sufficiently profitable for growers, has been a major obstacle to growing this fledgling industry both locally and internationally.

This project addressed a broad range of black carrot production issues. This was achieved by evaluating approximately 30 individual field trials and commercial crops, mainly in the south-eastern Australia (SA Mallee, Mildura, Tasmania, and Southern Victoria) as well as prospective northern production areas (Darwin, Katherine, Bowen). Key lines of enquiry and findings included:

- Extreme vernalization sensitivity of the key current variety. Any exposure to average day temperatures of about 16°C or less in the first 3-4 weeks after planting resulted in unacceptable levels of "early" bolting.
    - Following from this, the creation of a basic model for growers to determine the likelihood of crops bolting when planted at different times of the year, based on historic or live weather data.
    - Identification of both traditional and prospective new production regions in Australia to allow year round supply.
- Essential nutritional requirements for black carrots were found to be similar to conventional high carotene carrots on a rate per ha basis but higher on a rate per ton of harvestable product.
- Attempts to divert plant resources away from vigorous canopy production into more useful carrot production, by manipulating nitrogen inputs, irrigation, plant density or using chemical growth regulators were not found to be broadly effective.
- The plant spacing that maximised harvestable yield and average carrot weights while minimising undersize (unharvestable) yield was 40-50mm in most situations.
- The importance of heat as a key cause of poor germination and plant establishment as well as being the likely cause of seedling decline.
- Higher frequencies of forking were associated with extreme heat at or soon after planting.
- Black carrots were not found to be any more susceptible to the more common damping off pathogens than conventional high carotene carrots, nor did any of these prove to be the most important contributing factors to poor crop establishment.
- Fungicides applied as soil drenches did not significantly improve the harvest quality or yield for the processing market (as disease was not found to be the major cause of harvest quality or yield losses).
- Black carrot tolerance to the herbicides linuron and prometryn was similar to conventional high carotene carrot lines.
- The larger canopies and rapid growth rate of black carrots indicate higher water requirements than for conventional orange carrots, particularly during early growth to maximise yield and quality.
- While other high anthocyanin lines were evaluated, the variety Excelfresh LX3632 remains the current industry standard.
- An Agronomic Guide to growing black carrots in Australia based on best current information was produced.

Technical Summary

Carrot juice production has for a long time been the lowest value sector in the Australian carrot industry. Much of the production comes from rejected fresh carrots, usually related to size or shape specifications. In addition, the major global market for carrot juice concentrate is Japan with very little domestic consumption. However, the interest in functional foods, particularly fresh fruit and vegetables rich in anti-oxidants, combined with the recent commercial availability of a highly unusual line of carrots, rich in anthocyanins, presents the industry with a real opportunity to reintroduce some profitability into the processing carrot market. Australia has already established a reputation for being able to grow black carrot crops with superior anthocyanin levels compared with many overseas competitors in Europe for example.

From the outset some years ago, it was clear that these “black” carrots could not simply be substituted into conventional high carotene production systems. Considerable difficulty in growing satisfactory commercial crops that were both acceptable to processors and sufficiently profitable for growers, has been a major obstacle to growing this fledgling industry both locally and internationally.

This project addressed a broad range of black carrot production issues. This was achieved by evaluating approximately 30 individual field trials and commercial crops, mainly in the south-eastern Australia (SA Mallee, Mildura, Tasmania, and Southern Victoria) as well as prospective northern production areas (Darwin, Katherine, Bowen). Key lines of enquiry and findings included:

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- The plant spacing that maximised harvestable yield and average carrot weights while minimising undersize (unharvestable) yield was 40-50mm in most situations.
- The importance of heat as a key cause of poor germination and plant establishment as well as being the likely cause of seedling decline.
- Higher frequencies of forking were associated with extreme heat at or soon after planting.
- Black carrots were not found to be any more susceptible to the more common damping off pathogens than conventional high carotene carrots, nor did any of these prove to be the most important contributing factors to poor crop establishment.
- Fungicides applied as soil drenches did not significantly improve the harvest quality or yield for the processing market (as disease was not found to be the major cause of harvest quality or yield losses).
- Black carrot tolerance to the herbicides linuron and prometryn was similar to conventional high carotene carrot lines.

- The larger canopies and rapid growth rate of black carrots indicate higher water requirements than for conventional orange carrots, particularly during early growth to maximise yield and quality.
- While other high anthocyanin lines were evaluated, the variety Excelfresh LX3632 remains the current industry standard.
- An Agronomic Guide to growing black carrots in Australia based on best current information was produced.

1 Introduction

Carrot juice production in Australia is centred around the Mallee regions of Victoria and South Australia and the Riverina in southern NSW. There are two main processors that service the region. Some of the production comes from dedicated processing varieties like "Red Hot" or "Apache" but much of it also comes from carrots rejected as misshapen, forked, under or oversized for the fresh market. Most of this carrot juice is destined for the Japanese market as a bulk product reduced to a concentrate in 200L drums. Very little is consumed domestically. This makes it a low value industry that could benefit considerably from a higher value product. Pre-eminent as a contender is the black carrot.

Contrary to popular belief these are not in fact new, nor are they genetically modified. Along with yellow coloured carrots, they are sometimes referred to as "eastern" carrots and are in fact a very old genetic line that probably pre-date the "western" (orange) carrot.

With a growing interest in functional foods or at the very least a growing appreciation of the health benefits that accrue from a high intake of highly pigmented fresh fruits, vegetables and nuts, interest in a number of new carrot lines is gaining momentum. Traditional orange carrots are high in Beta-carotene, but there are white or yellow carrots high in luteins, red carrots high in lycopenes and perhaps most interesting of all purple or "black" carrots high in anthocyanins. All of these pigments are antioxidants and many have been associated with a whole range of medical benefits, beyond the scope of this introduction. In a recent study, carrots found to have the highest antioxidant capacity contained anthocyanins (Sun *et al*, 2009). In addition to anthocyanins, purple carrots have also been found to contain other compounds with potential health benefits. Metzger *et al* (2008) suggested polyacetylenes rather than anthocyanins in purple carrots are responsible for anti-inflammatory bioactivity.

Interest in purple carrots has started with the production of juice, extracted and concentrated using much the same process as that used for high carotene juice production. This has gone to Japan and then been blended into various fruit juices. But in more recent times, domestic interest been heightened even as this project concludes. Greg Jardine ("Dr Red Nutraceuticals") has begun selling health products based on the juice concentrate (selling over $1 million of the product "Olevine Purple Carrot" in the first year) but is also looking at other methods of extracting anthocyanins in a crystalline form. Over the last 12 months or so, Greg Jardine has been working with Professor Lindsay Brown from the School of Biomedical Science at the University of Queensland to assess the health benefits of purple carrots in a rat model of diet-induced obesity, hypertension and glucose intolerance. This work was given high level media exposure in a recent television article on "A Current Affair" (http://aca.ninemsn.com.au/article.aspx?id=990665). There was considerable interest from a number of small growers following this event.

While the market has gathered pace in recent months, there was considerable difficulty for most of the project in finding commercial co-operators prepared to grow black carrots. No contracts for production were negotiated between SDS Beverages and prospective growers between the start of the project and when SDS went into receivership in 2009. At the beginning of the project, there were many agronomic reasons that made growing black carrots far more difficult than conventional high carotene types. This project set out to identify the key differences and difficulties with the current industry standard black variety LX3632 and provide a number of recommendations, including an agronomic guide for growers on best practice for growing this variety.

The key challenges and problems this project sought to address were:

Sensitivity to bolting: Black carrots have been found to bolt severely in many southern plantings. The key stimulus for this in carrots is cold (vernalization). Identifying what level of exposure to cold (critical temperature and length of time) was critical in identifying safer planting windows for future production. In addition to this, limitations on seasonal production in the south meant the need for identifying areas in the north that could be used to schedule crop production at other times.

Canopy management: Black carrots have far more vigorous canopies than conventional orange varieties and in the first half or more of the production cycle have smaller carrots at the same age. This strongly suggests black carrots are diverting a much lower proportion of photosynthates away from the canopy into carrot production. A number of lines of investigation were followed to see whether this could be manipulated to improve carrot yields and reduce excessively vigorous canopies. Key methods investigated were nitrogen nutrition, water management, chemical growth regulation and crop density.

Poor germination and plant establishment: While this is actually quite a common problem in carrots generally, black carrots seemed to be especially susceptible. There were a whole range of factors that could be playing a role. Key lines of enquiry were ambient & soil temperature effects on seed, seed viability, irrigation regimes used, any clear seedling or soil-borne disease problems and sensitivity to the herbicides linuron and prometryn.

Improved harvest yield and quality: Black carrots tend to produce high numbers of smaller carrots. They appear also to fork more readily than standard orange lines. A range of contributing factors including nutrition, irrigation, plant densities to balance yield and size, and controlling soil borne diseases after the plant establishment phase were studied.

New varieties: In the first year several other new lines of pigmented carrot were evaluated against the existing industry standard LX3632. No new lines were available in the subsequent season. The one advantage of using a single variety for all the other studies, was the volume of data that could be directly compared. This was especially true for the development of a basic bolting model for LX3632.

Technology Extension: There are key findings summarised at the beginning of each report section. In addition, a black carrot agronomy guide was written that assembles the most current information generated from the project. It is intended for existing carrot growers looking for information on how black carrots differ from ordinary high carotene carrots and what particular additional steps need to be taken to produce higher yielding and better quality crops than has been the case up to now. Recommendations have often drawn on limited data and this needs to be born in mind, given the broad range of issues studied in this project in a limited time.

Many of the studies that set out to provide answers to one set of questions often ended up providing valuable information for others. This means that results relevant to the different sections of this report have been separated out from some trials and included in those sections.

References

Metzger BT, Barnes DM, Reed JD (2008). Purple Carrot (Daucus carota L.) Polyacetylenes Decrease Lipopolysaccharide-Induced Expression of Inflammatory Proteins in Macrophage and Endothelial Cells. *Journal of Agricultural and Food Chemistry*. 56 (10) 3554-3560.

Sun T, Simon PW, Tanumihardio SA (2009). Antioxidant Phytochemicals and Antioxidant Capacity of Biofortified Carrots (*Daucus carota* L.) of Various Colors. *Journal of Agricultural and Food Chemistry*. 57 (10) 4142-4147.

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Greg Jardine – Dr Red
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2 General Materials and Methods

Project studies were intended to be a combination of both small plot replicated and large scale commercial trials. However, other than the initial evaluations at Olive Grove (Robinvale, Victoria) and Premium Fresh (Devonport, Tasmania) early in 2007, commercial contracts between SDS Beverages and prospective growers were not successfully negotiated. This meant that large scale trials implementing best practice agronomy based on project findings and recommendations were simply not possible. However, much of the research was still conducted on carrot producing farms including several large scale strips planted with commercial equipment and managed alongside conventional high carotene types.

Trials were conducted over an extensive range of environments and prospective growing regions in the initial period. Plantings were evaluated in Darwin and Katherine in the Northern Territory, Bowen in Queensland, Devonport in Tasmania, Clyde and Robinvale in Victoria, Dareton in NSW and Parilla in South Australia. However, the bulk of the field work was conducted in the major production area supplying SDS Beverages in the Mallee regions of NSW, Victoria and SA. The planting period for high carotene processing carrot production in the main Southern Australian region is late Spring (Oct-Nov) through to early Autumn (Mar). The sowing of black carrots was then confined to this period for the majority of the work undertaken.

Bed & Row Configurations

All trials were conducted on carrot beds using one of two widely used commercial configurations; either “10/40/10” or “7/27/7/27/7” as detailed below. Beds were normally spaced 1.6-1.7 m apart.

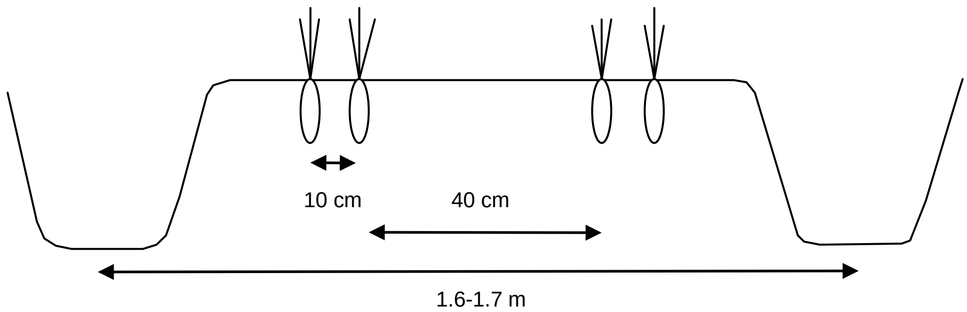


Figure 1.1 – Configuration Type 1 – 10/40/10 (2 paired rows per bed)

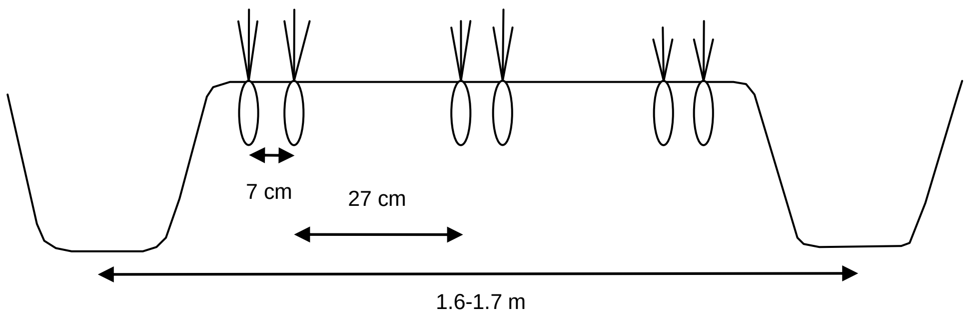


Figure 1.2 – Configuration Type 2 – 7/27/7/27/7 (3 paired rows per bed)

Rotations

Carrot rotation practices are many and varied. Some growers grow successive crops without a significant break between crops, although this was not a widespread practice. Larger growers achieve the best yields by typically rotating with a crop of potatoes and a crop of onions before re-planting carrots. Trials covered this full range of rotations.

Seeding

All trials were established from seed and the majority of the trials ran through to commercial harvest timing. Seeding was generally done by hand, a very labor intensive task due to establishment difficulties using other techniques. Several of the earlier trials were sown using seed tape, whereby seed was inserted into a cellulose based tape at relatively regular 10 mm spacings and wound onto a reel by a purpose built machine. At planting, the reel was mounted onto a modified, single row "Earthweight" type seeder and pushed along the ground, lying the tape and seed in a line just beneath the soil surface. After irrigation, the cellulose tape dissolved, leaving the seed at regular intervals in the ground. In the case of large scale trials, seed was sown with conventional commercial seeding equipment, which in all cases was a vacuum seeder.

***Photo 2.1**: Spool of seed tape used for planting a number of early trials but abandoned in later work due to problems with seed viability.*

Photo 2.3*: Marking seed furrows with a nail jig for 10/40/10 row spacings.*

***Photo 2.3**: Painstaking method used for planting density trial, with discrete bundles of seed dropped at planting points and thinned to a single plant after emergence.*

***Photo 2.4**: Metre lengths of pvc pipe with planting density intervals (mm) used in the density work.*

***Photo 2.5**: Aluminium flashing fashioned into a seed shoot for dribbling seed into opened furrows before brushing sand back over and gently firming by hand.*

Crop Nutrition

Fertilizer was applied at rates used for normal commercial carrot crops on the farms in question in all cases, except where specific nutrition trial work was conducted. This typically consisted of a minimal dose or even no basal NPK + trace elements, followed by small, regular does of fertilizer, particularly N (usually as urea) through fertigation. Organic fertilizers such as fowl manure were not generally used. Small plot trials were mainly fertilized after establishment using regular low doses of complete soluble fertilizer, particularly Hortico™ Aquasol (N:P:K = 23:4:18).

Crop nutrition measurements in were taken in two ways. Mostly, foliage was used to estimate nutrient levels and requirements, using dry-ash analyses. Foliar samples were always taken using the youngest mature leaves (YML) usually from at least 10-20 plants per sample. Several samples of carrots were also analysed by the dry ash method to allow the calculation of nutrient removal.

Complete nutrient analyses from soils were done in any cases where nutrition was thought to significantly or potentially contribute to the trial results.

Soils

Soil types were almost universally sandy or sandy loams, ranging from iron rich red Mallee sandy loams though to yellow Mallee loams with some duplex character to black sands in Southern Victoria. All trials were conducted on beds except for the Dareton trials where it was neither feasible or necessary because in this region soil drainage was excellent.

Irrigation

Watering was done in most cases by solid set overhead sprinklers or centre-pivot irrigation. In certain instances for reasons outlined in the relevant sections, drip irrigation was used, although this is not yet a widespread commercial practice. Crops typically received 8 mm or more per day during the hottest part of the growing season (Southern Australian Summer). Water sources varied from ground and river water, to A grade recycled water.

Crop Protection

Weed control was achieved in all cases by use of linuron and/or prometryn, both pre and post emergent herbicides, at label or below label use rates as more comprehensively detailed in the Herbicide section of this report.

Serious infestations of insects and diseases were not generally experienced in trials once crops were established and no specific remedial action was generally required. That said, there were specific studies undertaken to determine whether fungal diseases commonly played any significant role in crop establishment or harvest quality. Sclerotinia can also be a common problem in commercial carrot crops requiring a sequence of fungicide applications to control. However, this was never a serious issue in these trials so routine spraying was not necessary.

Crop Establishment

After the initial problems were experienced with seed tape, subsequent trials were sown by hand at very high rates and then thinned by hand to a uniform and optimum spacing after emergence, typically 30-35 mm. This was done to achieve a high degree of consistency in the small plot trials, thereby reducing variance not associated with direct treatment effects.

Harvest & Parameters Assessed

Harvesting was done by hand, taking samples from all rows across the beds, typically 1.0 linear metre of bed (4-6 metres of total carrot row). Usually irrigation was applied to loosen the carrots, immediately before digging with a garden fork. All carrots were recovered, including the smallest to account for typical losses as well as harvestable material.

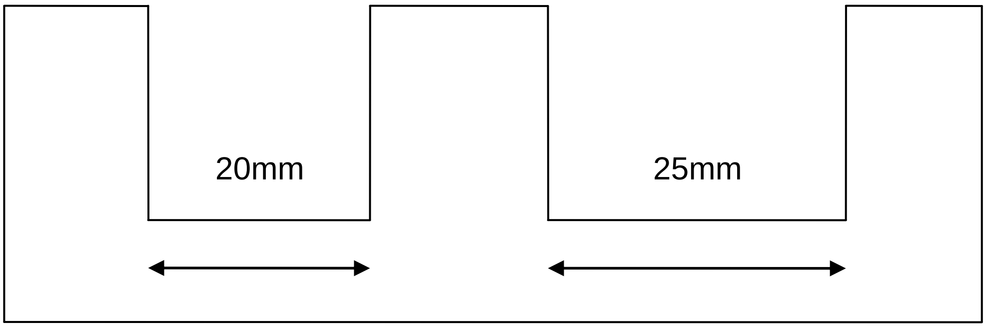
Top weights were measured by breaking them off individual carrots at the crown, similar to typical commercial harvesting equipment. Top weights were recorded as fresh weights only.

Harvestable yield was determined by removing carrots deemed to be too small to be reliably harvested with commercial harvesting machinery and those that had clearly bolted.

Carrots were usually graded into three size categories based on the greatest width at the shoulders (crown): >25 mm, 20-25 mm, >20 mm. For juicing, all carrots in these trials could have been used but the limitation for yield is what material can be physically harvested. This relates to the ability of the machinery to separate carrots from the soil and deliver it into harvest bins. The three grades described are based on measurements of conveyor gaps and mesh sizes on typical harvesters, material left behind in the field, the size of the smallest carrots recovered from bins arriving at the factory, and processor preferred minimum size. Some harvesters appear to be able to recover reasonable numbers of carrots as small as 20 mm while others are not particularly effective below about 25 mm. In addition, losses through peeling at the factory are particularly severe when carrots fall below 20-25 mm. Harvesters do not successfully recover all commercial grade (>25 mm) carrots either but there tends to be more smaller carrots in any examination of carrots remaining behind after harvesters have moved though a row.

***Photo 2.6**: Carrots were graded in most trials by sorting into three sizes according to crown or shoulder width (white arrow below). This was the widest part of the carrot. Where it was asymmetric, an average width value was used.*

***Figure 1.3**: Jig made from a timber block, used to measure and sort crown width categories.*



Where significant bolting occurred, "bolting adjusted" yield was determined by adjusting harvestable yields upwards by the proportion of material lost to bolting. For example, if a crop showed 6% bolting, the bolting adjusted yield was 100/94 multiplied by the non-bolting yield.

Photo 2.7*: Bolting plants are completely unharvestable and had to be removed from any yield measurements but included in analysis. Some bolters grew to around 180cm.*

Forking

Branching/forking is also a highly undesirable characteristic when carrots are to be peeled, so this parameter was also captured in most harvest assessments. The criteria for being counted as branched or not was based on whether the factory peelers were deemed likely to peel the carrot normally or not. In marginal cases where a very small single fork was found, the deformity was ignored.

Cracking

Cracking, primarily a response to insufficiently frequent or adequate watering, was assessed in some of the early trials but not in subsequent trials unless clearly linked to treatment effects.

Brix & Anthocyanin Measurement

After harvest, carrot samples were retained for laboratory analyses of both Brix and anthocyanins. This was sometimes done immediately after harvest and sometimes after cool storage at <4-5° C for up to several weeks but always while material was in sound condition.

Brix was measured using a refractometer.

Anthocyanins were measured by juicing and measuring light absorbance in a spectrophotometer at 538 nm. All samples were adjusted to 8.0° Brix before measuring absorbance. Absorbance values were used to calculate anthocyanin content (and as such are directly related) using the following formula):

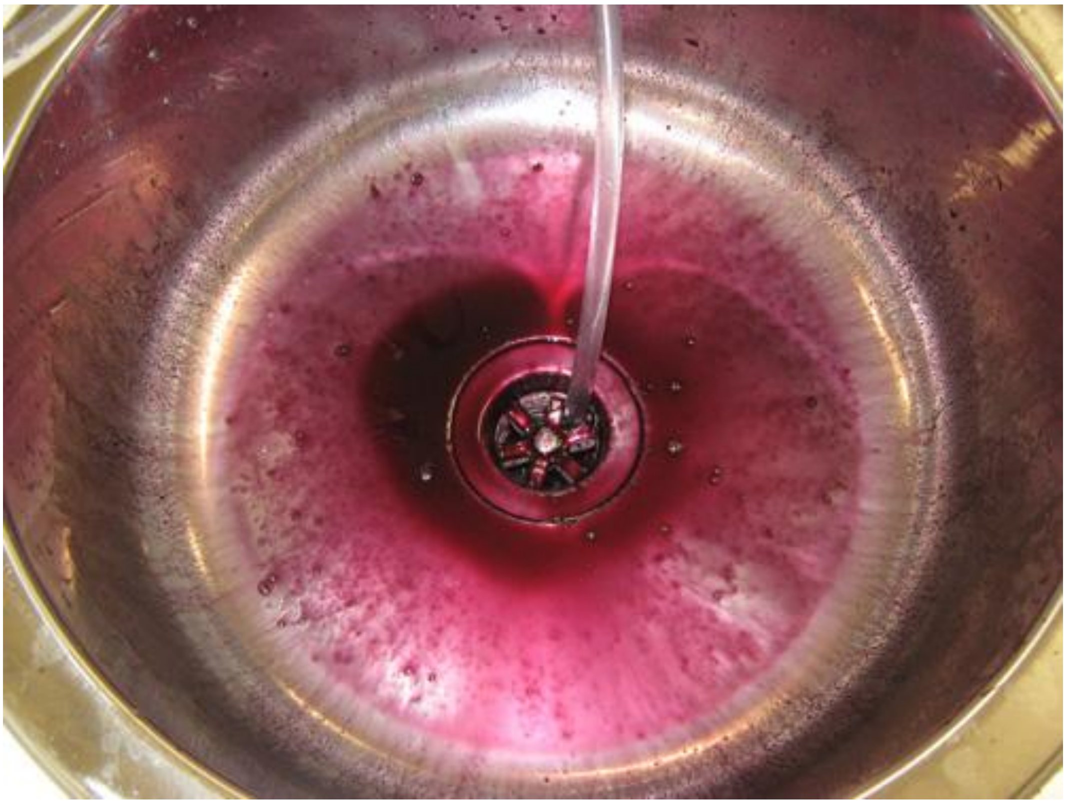
Anthocyanin [mg%] at 8.0° Brix = (Absorbance [538nm] x 100 x 322.7 x 100) / (31400 x sample weight [g])

Full details on laboratory methodology can found in the appendices.

Photo 2.8*: Whole plot samples were used for most anthocyanin measurements due to the high level of colour variation in any given sample*

***Photo 2.9**: Powerful anti-oxidant - Anthocyanins remained in good condition (2.9a) in whole carrots or frozen juice samples but exposed surfaces of juice oxidized within about 30-60 seconds contact with air (2.9b).*

2.9a



2.9b

***Table 2.1** - Trial Reference Index: Trials, commercial crops & other studies, as they are referred to in this report*

Study	Description	Type	Location	
BC0601	Scoping Study - Pre-project	Commercial crop	Nangiloc	Vic
BC0700	Scoping Study - Pre-project	Commercial crop	Devonport	Tas
BC0701	Scoping Study - Last Commercial Crop	Commercial crop	Robinvale	Vic
BC0702	Location Potential, Growth Regulation	Q DPI Research Station	Bowen	Qld
BC0703	Planting Time & Nitrogen Rate	NT DPI Research Station	Katherine	NT
BC0704	Location Potential & Planting Time	NT DPI Research Station	Darwin	NT
BC0705	Optimum Density & Harvest Age	Inside commercial crop	Clyde	Vic
BC0706	New Variety Evaluations	Inside commercial crop	Clyde	Vic
BC0707	Commercial Strip	Large inside commercial crop	Parilla	SA
BC0801	Nutrition & Canopy Management with Nitrogen	NSW DPI Research Station	Dareton	NSW
BC0802	Aborted First Watering Trial	NSW DPI Research Station	Dareton	NSW
BC0803	Chemical Growth Regulation	NSW DPI Research Station	Dareton	NSW
BC0804	Bolting Study Plantings	NSW DPI Research Station	Dareton	NSW
BC0805	Bolting, Emergence, Establishment, (Density) Studies	Inside commercial crop	Parilla	SA
BC0806	Commercial Strip	Large inside commercial crop	Parilla	SA
BC0807	Germination Test	Laboratory	Melbourne	Vic
BC0808	Density (Supplementary) Study	Inside commercial crop	Parilla	SA
BC0809	Thermogradient Germination Test	SPS Laboratory	Griffith	NSW
BC0901	Fungicides for Improved Harvest Quality	Inside commercial crop	Clyde	Vic
BC0902	Water Management	NSW DPI Research Station	Dareton	NSW
BC0903	Supplementary Fungicides for improved Harvest Quality	NSW DPI Research Station	Dareton	NSW
BC0904	Seedling Disease Control Using Fungicides	Inside commercial crop	Clyde	Vic
BC0905	Density (Supplementary) Study	Inside commercial crop	Clyde	Vic
BC0907	Seedling Disease Control using Fungicides	NSW DPI Research Station	Dareton	NSW
BC0908	Seedling Disease Control using Fungicides	Inside commercial crop	Parilla	SA
BC0910	Pre-emergence Herbicide Tolerance - Main Trial	Inside commercial crop	Tyabb	Vic
BC1001	Germination Test	Laboratory	Melbourne	Vic

3.1 Determining Optimum Harvest Maturity for Black Carrots

Introduction

As with other sections, much of the data contained in this section comes from a number of different studies not specifically set up to address this issue. Harvest maturity is dependent on the end use product which in carrots can vary from perhaps only 8-10 weeks of age for Dutch (bunching) carrots though to 110 days for some fresh carrots to 140 days plus for mature fresh carrots or for juicing carrots.

With high carotene carrots grown for juicing, the three most important attributes are harvestable yield, Brix & carotene levels. The same key attributes apply for black carrots except anthocyanin levels rather than carotene levels are critical. The key question then is how to maximize all of these without seriously compromising any one of them.

A few trials were harvested over several different dates and this gave the best statistical indication of harvest timing performance. The balance of information comes from analyzing trends from trials showing particularly good or poor results for particular harvest attributes.

Key Outcomes

- For processing, the ideal harvest maturity for LX3632 is likely to occur around 140-160 days after planting. Further work to fine tune this for different regions would be of value. Growers should use the onset of leaf senescence (about 1-5%) as a guide to full maturity being achieved and begin digging anytime after 140 days if there are any indications of late bolting beginning.

- Harvesting too early (typically 130 days or earlier) is likely to prevent Brix, anthocyanins and yield from reaching full potential.

- Harvesting too late (typically 170 days or later) runs the risk of late bolting and decreased foliage for harvesters to grip while lifting. However, it is unlikely to reduce Brix or anthocyanin levels. Yield may be reduced by rots, if harvested too late particularly if grown in warm northern climates.

- The most effective means currently identified for maximizing anthocyanins is to allow carrots to fully mature (140-160 days).

Materials & Methods

BC0705 – Clyde, Vic, 2007-08

Please refer to Section 4.

Evaluation:

Photographs were taken at various stages between emergence and harvest. Bolting was assessed 08 Jan 2008 (71 & 74 DAP(days after planting)). Harvest assessments were carried out on four separate dates, with one whole replicate harvested on that date (115, 120, 134 & 151 DAP) by harvesting 1.00m of bed (all 4 carrot rows) and assessing bolting, carrot numbers, weights, cracking and deformities. After taking photographs of whole samples, entire plot yields were packed in plastic bags and sent by overnight road transport to SDS Beverages in Merbein. Here they were cool stored for several weeks at 4° C, before being juiced. A 500 mL sample of juice was kept from each sample, frozen and subsequently analysed in SDS's Merbein laboratory for Brix using a refractometer and anthocyanin content using an absorbance spectrophotometer.

Statistical Analyses:
In all tables shown, vertical bars aligned in the same column indicate means that are NOT SIGNIFICANTLY DIFFERENT (LSD, P=0.05). Means followed by "-" failed Bartlett's Chi-squared Test for Homogeneity of Variance and attempts to rectify this with transformations were NOT successful (P=0.05). NSAP indicates no statistical analysis performed. Blue vertical bars indicate LSD results based on successfully transformed data BUT the numbers they follow are original.

Results

BC0705 – Clyde, Vic, 2007-08

Table 3.1.1 *BC0705: Carrot Yield Components – Raw Data (kg/ha), classified by Days – Planting to Harvest*

Days – Planting to Harvest	TOTAL Yield - Carrots NOT BOLTING (t/ha)	Days – Planting to Harvest	YIELD 21+mm - Carrots NOT BOLTING (t/ha)	Days – Planting to Harvest	YIELD 26+mm - Carrots NOT BOLTING (t/ha)
134	39.793 I	**134**	38.796 I	**134**	36.009 I
151	38.098 I	**151**	37.230 I	**151**	34.459 I I
120	33.803 I	**120**	32.804 I	**120**	29.452 I I
115	29.708 I	**115**	28.824 I	**115**	25.689 I

Table 3.1.2 *BC0705: Carrot Yield Components – Bolting Adjusted Data (kg/ha), classified by Days - Planting to Harvest*

Days – Planting to Harvest	TOTAL Yield - Carrots BOLTING ADJUSTED (t/ha)	Days – Planting to Harvest	YIELD 21+mm - Carrots BOLTING ADJUSTED (t/ha)	Days – Planting to Harvest	YIELD 26+mm - Carrots BOLTING ADJUSTED (t/ha)
134	49.869 I	**134**	48.706 I	**134**	45.403 I
151	47.920 I I	**151**	46.927 I	**151**	43.736 I I
120	44.554 I I	**120**	43.366 I I	**120**	39.290 I I
115	40.277 I	**115**	39.153 I	**115**	35.183 I

Table 3.1.3 *BC0705: Average Carrot Weight (g), Harvestable Carrot Weights 21+ & 26+ mm (g) & Crown Width (mm), classified by Days - Planting to Harvest*

Days – Planting to Harvest	Average Carrot Weight (g)	Days – Planting to Harvest	Average Carrot Weight 21+ mm (g)	Days – Planting to Harvest	Average Carrot Weight 26+ mm (g)	Days – Planting to Harvest	Average Crown Width (mm)
151	101 I	**151**	110 I	**151**	121 I	**151**	34.8 I
134	95 I	**134**	103 I	**134**	114 I	**134**	34.2 I
120	86 I	**120**	95 I	**120**	106 I	**120**	32.2 I
115	77 I	**115**	85 I	**115**	97 I	**115**	31.0 I

Table 3.1.4 *BC0705: Total Top Weight, Bolting Adjusted Top Weight (kg/ha) & Average Top Weight (g), classified by Days - Planting to Harvest*

Days – Planting to Harvest	Total Top Weight (t/ha)	Days – Planting to Harvest	Bolting Adjusted Total Top Weight (t/ha)	Days – Planting to Harvest	Average Top Weight (g)
120	25.181 I	**120**	33.5 I	**120**	66.4 I
115	24.247 I	**115**	33.1 I	**115**	64.9 I
134	19.713 I	**134**	25.1 I	**134**	50.1 I
151	19.436 I	**151**	24.0 I	**151**	24.7 I

Table 3.1.5 *BC0705: % Bolting at Harvest, classified by Days - Planting to Harvest*

Days – Planting to Harvest	% Bolting at Harvest
115	28.1 I
120	25.1 I
134	21.7 I
151	21.4 I

Table 3.1.6 *BC0705: Brix (^{0} Br), Absorbance & Anthocyanin Content at Harvest, classified by Days - Planting to Harvest*

Days – Planting to Harvest	Brix (°Br)	Days – Planting to Harvest	Absorbance (at 538 nm and 8.0^0 Brix)	Days – Planting to Harvest	Anthocyanin Content (mg/100 mL)
134	10.11 I	**120**	0.547 I	**120**	56.2 I
151	9.66 I	**151**	0.408 I I	**151**	41.9 I I
120	8.98 I	**115**	0.272 I	**115**	27.9 I
115	6.08 I	**134**	0.267 I	**134**	27.4 I

Table 3.1.7 *BC0705: % Forking, % Cracking & % Carrots with Enlarged Fibrous Roots at Harvest, classified by Days - Planting to Harvest*

Days – Planting to Harvest	% Forked Carrots	Days – Planting to Harvest	% Cracked Carrots	Days – Planting to Harvest	% Carrots with Enlarged Fibrous Roots
120	7.95 I	**115**	0.00 I	**151**	6.39 I
151	8.89 I	**120**	9.69 I I	**134**	8.82 I
115	10.81 I	**134**	7.85 I	**120**	9.37 I
134	12.17 I	**151**	13.37 I	**115**	9.73 I

Figure 3.1.1 *BC0705: Total Carrot Yield (Raw – NOT Bolting) at different Plant Spacings (mm), classified by Days - Planting to Harvest*

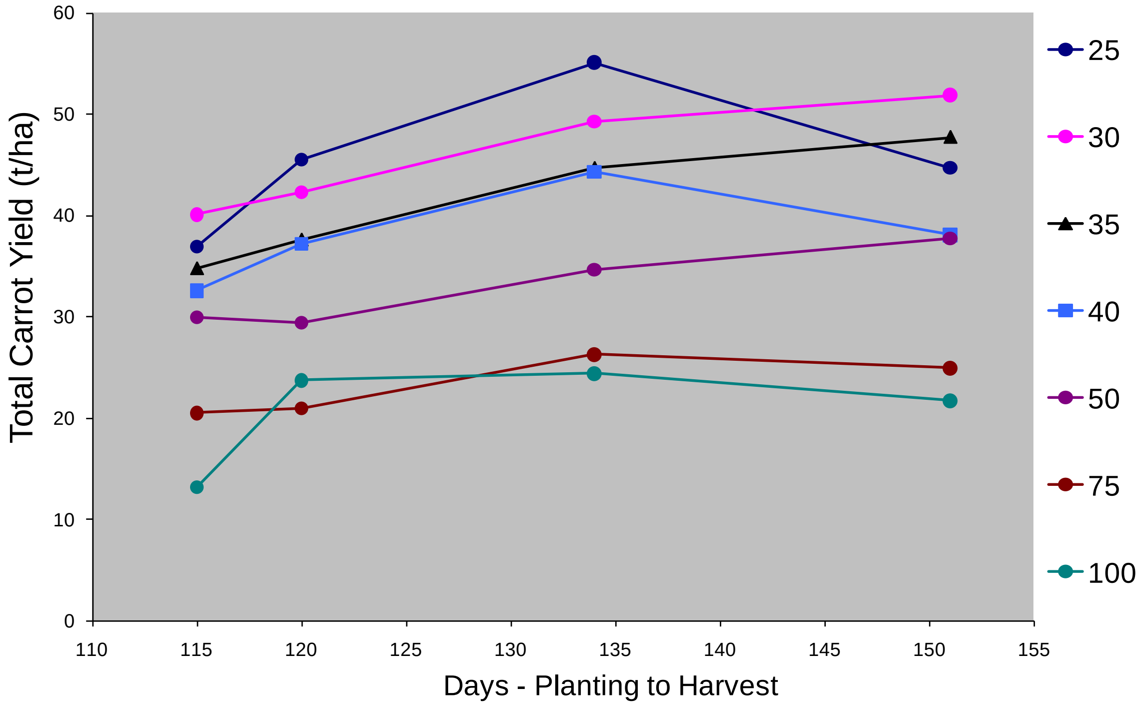


Figure 3.1.2 *BC0705: Average Carrot Weight (g) & Crown Width (mm), classified by Days - Planting to Harvest*

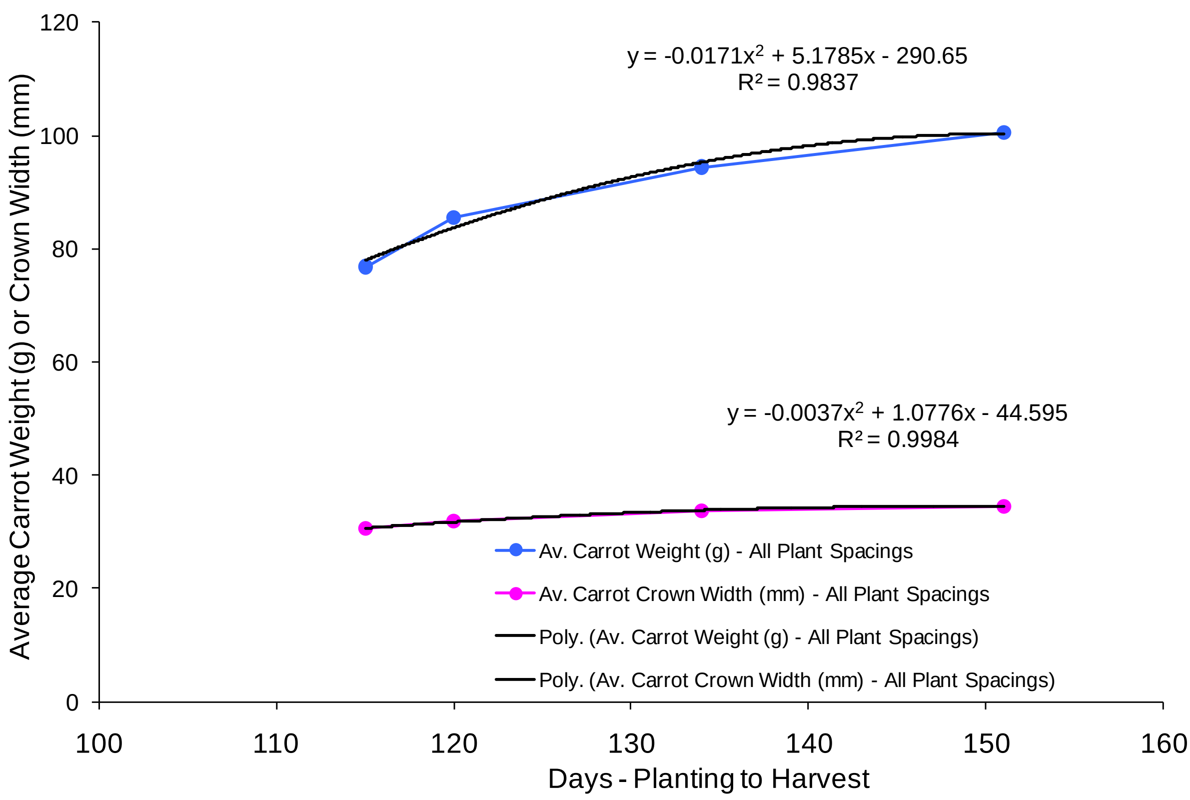


Figure 3.1.3 *BC0705: Average Carrot Weight (g) at different Plant Spacings (mm), classified by Days - Planting to Harvest*

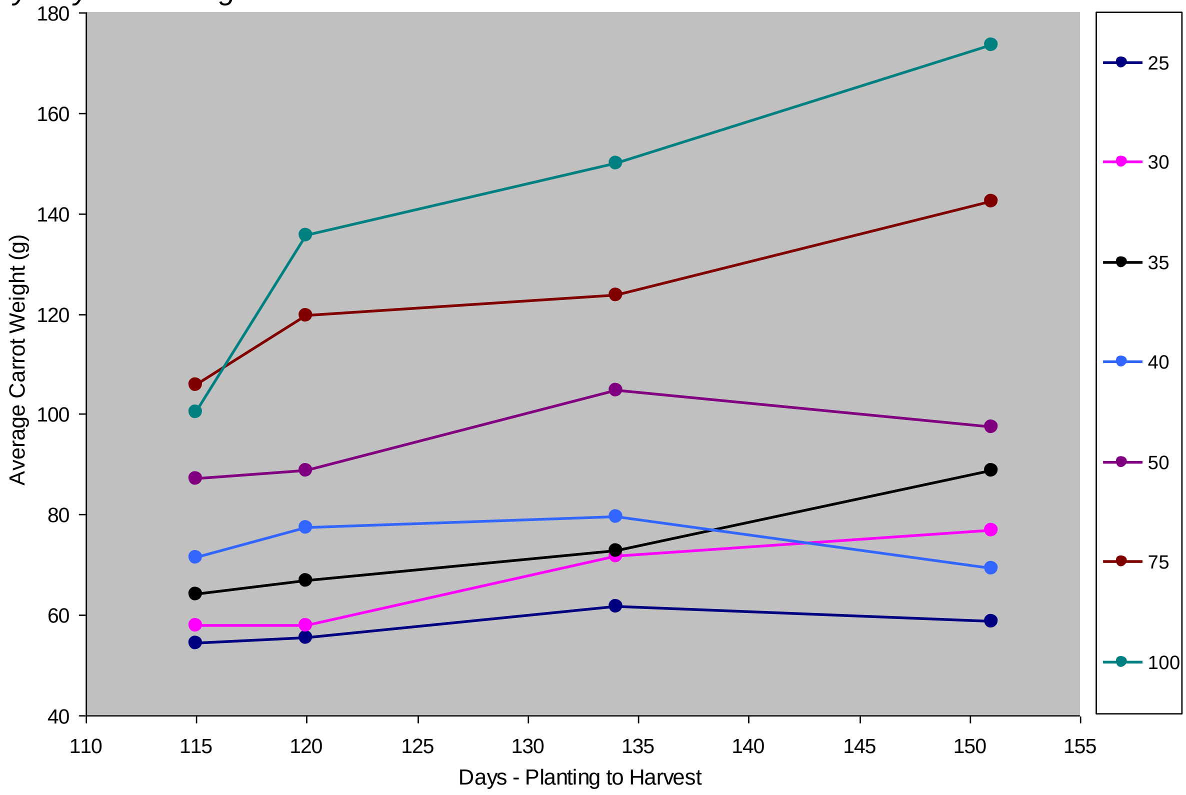
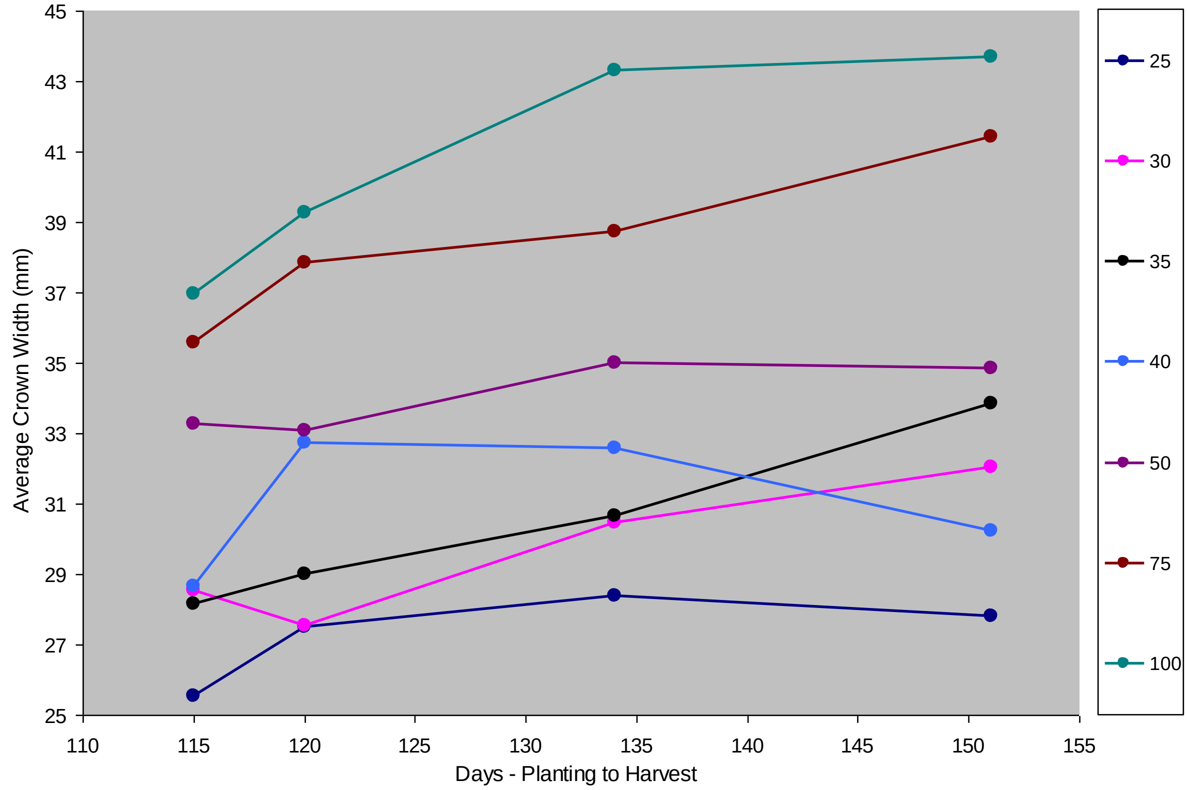


Figure 3.1.4 *BC0705: Average Carrot Crown Width (mm) at different Plant Spacings (mm), classified by Days - Planting to Harvest*



Discussion

The primary purpose of this trial was to identify the ideal planting density (Section 4) but as detailed measurements were taken for many parameters it became necessary to harvest on different dates and became an opportunity to obtain maturity related information to help determine an ideal harvest age. The uniformity of the plant stands at this site allowed reliable comparisons of this kind to be made and provide the data to illustrate some clear trends in results. There were four harvest dates and seven replications on each (one of each planting density) harvested on each date.

The first day for harvesting was selected as being at the very early end of a standard carotene juicing carrot harvest window (115 days) and the final date similar to a mid-late maturing crop for the same purpose (151 days).

Bolting (Table 3.1.5 & Figure 6.2)
As one of the earliest trials, the extreme sensitivity to early bolting had not been clearly identified and the trial was initiated when the best conventional (orange) carrots were grown in the same area. Serious early bolting made it necessary to adjust yield figures upward by the proportion of bolting carrots found in individual plots. Both adjusted and raw yields are given however.

As bolting was the product of early exposure to cold, flower heads were fully developed well before harvest and no new heads emerged during the harvesting period as reflected in the data.

Yield Components
Carrots with a crown width less than 21 mm and less than 26 mm were separated, weighed and counted. The same was done for all larger carrots with no upper size limit. This allowed harvestable yields to be calculated using a minimum shoulder width specification of 21 or 26 mm.

Raw Carrot Yields (Table 3.1.1 & Figure 3.1.1)
Raw plot yields consisted of all non-bolting carrots from largest to smallest harvested in each plot.

Total carrot yields increased markedly from 115 days to 134 days but with no yield increase at 151 days. Harvestable yields reflected precisely the same trend.

Figure 3.1.1 separates out the individual replicates (plant densities) which is interesting in two ways. Firstly it shows the different densities themselves did not behave remarkably differently, so any interaction from these with the harvest dates can be discounted. Secondly, between the last two harvest dates, three densities showed a slight increase in yield, while another three decreased. Those that increased were spread across the range as those that declined were. This indicates the combined result that lead to a slight numerical decline in yields between the two last dates is not so much a real decline in yield as a sampling aberration.

Bolting Adjusted Carrot Yields (Table 3.1.2)
Adjusting for bolting made no difference to the trends as the level of bolting was related to plant density (Section 4) not to harvest maturity. It did however show the trend was significant, something not shown with the raw (unadjusted) data, with total and harvestable yields not increasing beyond 134 days.

Average Carrot Weights (Table 3.1.3 & Figures 3.1.2 & 3.1.3)
Figure 3.1.2 shows that average carrot weight was extremely well correlated with harvest date (R^2 = 0.98), even though LSD analysis of the same results (Table 3.1.3) did not.

Unlike, the yield results which showed no increase after 134 days, average carrot weights continued to increase all the way to 151 days.

Figure 3.1.3 which splits out the seven replicates (densities), shows on balance more increased (4) than decreased (2) between 134 and 151 days.

Average Carrot Crown Width (Table 3.1.3 & Figure 3.1.2)
Average crown width is an interesting measure to read in conjunction with the average weight data. The trends with crown width strongly reflect average weight, showing carrots were not just growing longer but wider at the crown as well. Figure 3.1.2 shows the correlation between days to harvest and average crown width to be exceptionally well correlated (R^2 = 0.998).

Canopy Weights, Adjusted Canopy Weights & Average Top Weights (Table 3.1.4)
Canopy weights peaked around 115-120 days and then steadily declined to 151 days. This was evident in clear senescence of carrot tops, particularly on the last day of harvest. This suggests this may be a simple indicator of harvest maturity based on the favourable characteristics of carrot harvested at the same time.

Brix, Absorbance & Anthocyanin Content (Table 3.1.6)
Brix increased steadily to 134 days and declined slightly by 151 days. This end decline may be just a sampling effect. If not, it is likely the declining canopy was reducing the flow of sugars to the carrots in this time. The most significant increase in Brix occurred between 115 and 120 days.

Any statistical differences in the anthocyanin results are aberrations as the highest reading came at 120 days and the lowest at 134 days.

Carrot Forking, Cracking & Production of Enlarged Fibrous Roots (Table 3.1.7)

Forking was not found to be a function of harvest age. Damage to the tap root giving rise to forking and "stumping", side shoot development and fibrous roots are normally associated with disease, nematodes or physical damage, particularly during early development. Deformities of these types were commonly problematic on the farm where this trial was conducted. Recent attempts by the grower to identify the likely causes indicated that nematodes were not present and that *Pythium* was the most likely cause. A detailed record was made for individual carrots from each plot sample in case important trends emerged.

Cracking is a significant problem in conventional B-carotene carrots like Red Hot, not just black carrots. Cracking became more of a problem the longer harvest was delayed. Larger carrots are more prone to cracking and delaying harvest resulted in larger carrots. Watering was also probably less than ideal for the more mature harvest dates and would have been increased in a commercial crop to reduce the problem.

The incidence of enlarged fibrous roots did not increase with crop age and was relatively consistent (numerically decreased in fact) across harvest dates.

Additional Data

Table 3.1.8 *Table showing sites where comparable plantings from the same season were harvested at different ages and the resulting harvest yields and qualities.*

Study	Plant	Harvest	Age	Antho-cyanin (mg%@ 8.0°Br)	Brix (°Br)	Total Yield (t/ha)	BAJ Total Yield (t/ha)	Harv Yield >25mm (t/ha)	BAJ Harv Yield >25mm (t/ha)	Av. Carrot Weight (g)	Av. Carrot Weight >25mm (g)
BC0805	19/11/2008	30/04/2009	162	82	11.2	55.5	69.1	44.4	55.8	65.4	99.9
	10/12/2008	1/05/2009	142	56	10.6	71.5	75.8	57.1	60.5	68.7	98.9
	1/01/2009	6/07/2009	186	79	11.2	38.2		28.5		35.6	62.6
	1/01/2009	20/07/2009	200	101	14.1						
BC0703	24/05/2007	1/10/2007	130	87	12.0	23.6				45.0	
	14/06/2007	1/10/2007	109	48	11.5	21.7				40.0	
BC0706	7/11/2007	13/03/2008	127	35	10.1	41.6	48.7	41.3	48.4	74.0	
BC0905	12/02/2009	6/08/2009	175	66	11.1	34.6		30.3		50.3	71.8
BC0901	3/02/2009	28/07/2009	175	75	10.1	34.5		31.6		54.5	76.8

BAJ = Bolting Adjusted Yield as appropriate. No entry means adjustment was not required.

The table above contains additional data used to assist in identifying optimum harvest maturity for LX3632. Results shaded the same colour are directly comparable with each other:

BC0805 – Parilla, SA 2008-09

A series of 5 plantings were made on the same property over the same season. Only three were of value in harvesting.

Plantings 1 & 2 were made in the same beds and showed an increase in all key indicators, except for average carrot weight, from 142 to 162 days.

Planting 3 was made in a much poorer area of a different paddock (duplex with shallow clay pan) and this is reflected in the poor yield and average carrot weight. Interestingly, even at 186 days this crop had still not begun to bolt. A sample taken a fortnight later after the paddock had been harvested and the irrigation turned off showed very high Brix and anthocyanins, most likely through some loss of carrot moisture. This level of Brix in particular is very unlikely to be achieved in an ordinary crop, even when very well managed.

BC0703 – Katherine, NT, 2007

Harvest dates for this crop were at an ideal time to show the changes occurring between 109 & 130 days, but would have been premature in a commercial crop. Both anthocyanins and Brix showed considerable development over the 21 days between the two crops. However, yields and average carrot size showed little change.

BC0706 – Clyde, Vic, 2009

This is included as a comparator to the earlier sown crop used in the main study of this section (BC0705), which was sown in immediately adjacent beds at similar times. The harvest indicators all fit inside the range seen in the main trial which covers harvest times earlier and later than BC0706.

BC0901 & BC0905 – Clyde, Vic, 2009
These trials were located in adjacent beds and staggered by nine days exactly for both sowing and harvest. These were possibly slightly mature, with some bolting having begun but not enough to complicate harvest results. As might be expected, there was very little difference for key yield and quality indicators.

3.2 Modelling, Predicting & Reducing Bolting in Black Carrots

Introduction

Early on in the project it became very clear that the single, most important issue to address was bolting.

Black carrots are extraordinarily sensitive to vernalizing temperatures compared with virtually all commonly grown modern varieties of orange carrot. Bolting after exposure to a critical minimum period of cold is a trait which has been very successfully selected out of most modern carrot varieties, allowing year round production in many regions of Australia.

Several dedicated plantings were made in selected southern regions at different times to relate periods of cold exposure to levels of subsequent bolting. In the main though, this data was collected from every planting of black carrots made by relating weather data, taken mostly but not exclusively from regional Bureau of Meteorology (BOM) weather stations, to levels of bolting subsequently observed.

Literature Review

No literature concerned with bolting or vernalization specifically relating to black carrots was found. For such a well established crop, current understanding of bolting in carrots more generally appears quite limited. The most extensive original studies used for processing LX3632 data in this project were those of Craigon *et al* (1990) & Atherton *et al* (1990).

Plants may have a specific cold-temperature hastening of flowering called vernalization (Roberts and Summerfield, 1987). Exposure to a critical period of cold temperatures or vernalization has been accepted as the principle trigger for carrots initiating reproductive development for some time (Gassner, 1918). However, neither the duration of exposure nor the relative effectiveness of different temperatures has been precisely determined (Atherton *et al*, 1990).

The presence of a juvenile period for a time after germination when carrots are insensitive to vernalization is widely cited in the literature. The juvenile period may last until 8 leaves are formed (Atherton et al, 1990) or may be absent altogether with plants sensitive to vernalization as soon as the seed is imbibed (Chouard, 1960).

Carrot roots themselves seem to play an important role in vernalization. Carrots with the tops removed (stecklings used in carrot breeding) are routinely chilled after the best carrots are selected to induce flowering. These are then planted out in the field to regrow tops and set seed. However if first crop whole plants are taken from the field, the buds will only set seed on being re-planted if they remain attached to the carrot during the chilling process (Chouard, 1960). Many bolting studies in carrots are in fact oriented towards improving rates of bolting for use in seed breeding. These studies typically investigate the effects of chilling periods on stecklings. Kahangi *et al* (1996), found that the carrot cultivar “Nantes” found the minimum thermal time for any flowering to occur was 126° Cd (Celcius days) and the optimum for 100% bolting was about 400° Cd. They also found the maximum temperature for vernalization was under 15°C, with no effective vernalization of stecklings at this temperature even after 10 weeks exposure.

Cardinal temperatures for vernalization in carrots most commonly referred to still seem to be those of Atherton *et al* (1990), with minimum (base), optimum and maximum temperatures of -1.0, 6.5 & 16°C respectively. There have been attempts to reanalyze this data for example to develop a curved (Yan and Hunt, 1999) rather than linear or “wigwam” (see Figure 3.2.1) model that has a sharp decline in vernalization above or below the optimum vernalization temperature. However, no new studies with original data and specifically relating to carrots were found.

References

Atherton JG, Craigon J, Basher EA (1990). Flowering and bolting in carrot. I. Juvenility, cardinal temperatures and thermal times for vernalization. *Journal of Horticultural Science* **65** (4) 423-429.

Chouard P (1960). Vernalization and its relation to dormancy. Annual Review of Plant Physiology **11** 191-239.

Craigon J, Atherton JG, Basher EA (1990). Flowering and bolting in carrot. II. Prediction in growth room, glasshouse and field environments. *Journal of Horticultural Science* **65** (5) 547-554.

Gassner G (1918). Beitrage zur physiologischen Charakteristik sommer- und winterannuellar gewasche inbesondere der Getreidpflanzen. *Zeitschrift fur Botanische* **10** 417-480.

Kahangi EM, Chweya JA, Akundabweni LS (1996). Cardinal temperatures and thermal times for vernalization in carrot cv. “Nantes”, *African Crop Science Journal*, **4** (1), 57-62.

Roberts EH, Summerfield RJ (1987). Measurement and prediction of flowering in annual crops. In: *Manipulation of flowering*. (Atherton JG, Ed). Butterworths, London 17-50.

Yan W, Hunt LA (1999). Reanalysis of Vernalization Data of Wheat and Carrot. Annals of Botany **84** 615-619.

Key Outcomes

Over the life of the project, bolting in the Excelfresh black carrot variety **LX3632** was found to follow one of two distinct pathways:

1. **"Late" Bolting**: Plants remain in vegetative growth for about 150-170 days before bolting is evident.

2. **"Early" Bolting**: Evidence of bolting can be seen by about 50-60 days.

NO crops were found to bolt in the intermediate period (between about 60 & 150 days). This suggests a relatively distinct threshold requirement for cold exposure during the first few weeks of crop development to either trigger immediate bolting or to commit to a long vegetative period.

Crops that did not receive adequate early cold exposure to early bolt would then remain vegetative for 150-170 days. This occurred regardless of how much subsequent exposure to vernalizing cold the crop experienced. This is the desired path for commercial carrot crops (non-seed crops).

Using the three cardinal temperatures for bolting (T_{base} = -1°C;$T_{optimum}$ = 6.5°C; $T_{maximum}$ = 16°C), thermal time (Cd) was defined as the level of exposure to an average day temperature less than 16.0°C, summed for the days in the first 21-28 days using an equation devised by Craigon *et al* in 1990 (details - next page).

An examination of the occurrence (or not) of early bolting in some 30 studies, showed:

- Exposure to NOT MORE THAN 3.0° Cd in the first 3 weeks or 4.1° Cd in the first 4 weeks did NOT trigger "early" bolting.

- Exposure to AT LEAST 7.9° Cd in the first 3-4 weeks was sufficient to trigger "early" bolting.

- The critical period of exposure to vernalizing temperatures leading to early bolting in LX3632 may be no longer than the first fortnight after planting but this needs confirmation through further work.

There were rare contrary results that did not fit this model. Until further refined, **this model should only be used as an indicative guide** for determining safe sowing dates to avoid bolting. Other factors may also affect or modify this model.

Prospective LX3632 growers can obtain a Microsoft® Excel® template of the model from AHR for live or historic climate data entry, to calculate the likelihood of significant bolting.

A broad, more practical guideline proposed given the sensitivity to any exposure to daily average temperatures below 16°C is:

"Avoid planting LX3632 if there are likely to be ANY daily average temperatures below 16.0°C in the first four weeks after planting".

Carrot Bolting Model Used

Based on available literature, the most in-depth analysis of cardinal temperatures for vernalization of carrots came from (Atherton *et al*, 1990 & Craigon *et al*, 1990). They established three cardinal temperatures for bolting in carrot variety Chantenay Red Cored:

T_{base} = -1°C (The **minimum** temperature that vernalization occurs at)
T_{opt} = 6.5°C (The **optimum** temperature for vernalization)
T_{max} = 16°C (The **maximum** temperature that vernalization occurs at)

Vernalizing Cd was defined as the level of exposure to an average day temperature less than 16.0°C, summed for the days in the first 21-28 days using an equation devised by Craigon *et al* in (1990):

(T_{eff} only calculated when b satisfies conditions below)

$$\text{Vernalizing° Cd} = 1 + T_{eff}$$

Where $T_{eff} = T_{opt} - [(A/B) \times b]$

T_{exp} = Actual Daily Average temperature **experienced**

T_{eff} = **Effective** vernalizing temperature

b = $T_{exp} - T_{opt}$ (**only when** $6.5°C < T_{exp} < 16.0°C$)

A = 7.5

B = 9.5

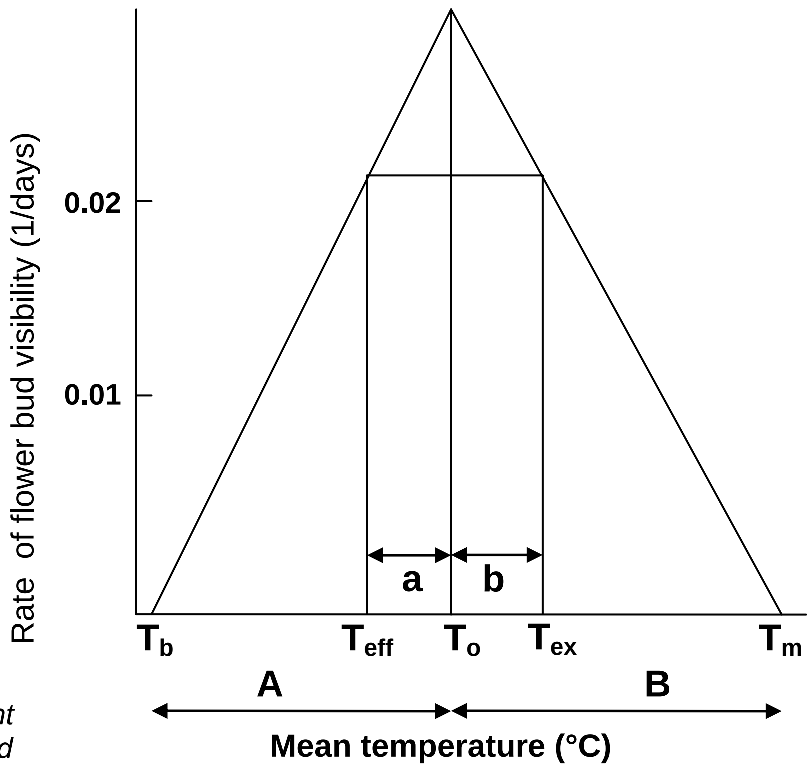


Figure 3.2.1

Reproduced from Craigon et al, 1990

The vernalization model developed for Chantenay Red Core to relate days to flower bud visibility with mean (daily) temperature was used to calculate thermal time for LX3632. The accumulated sum of thermal times that resulted in significant "early" bolting was then defined for LX3632.

This model was developed under more controlled conditions, making more specific measurements than simply “% bolting”. Figure 3.2.1 for example shows the model relating the rate of flower development (days to bud visibility). The earlier paper by Atherton *et al*, (1990), used the same kind of model to relate the onset of other reproductive structures such as days to internode or inflorescence appearance.

Nonetheless, LX3632 showed a distinctive “cut-off” in sensitivity to cold despite the complications of differences in individual plant sensitivities. Over a very narrowly defined period of cold exposure, carrots would either show virtually no significant early bolting (defined as <0.1%) or 6+%. This type of model seemed to best describe the behavior of LX3632 with the following qualifications:

1. **Early Bolting** – This is a description developed in this project to define a phenomenon not described in the previous literature reviewed. Most previous studies look at vernalization as an absolute requirement for cold relatively independent of crop growth stage but often after a minimum “juvenile” period when the crop is insensitive to cold. This project clearly linked sensitivity to cold with crop age and actually found LX3632 to have either a negligible juvenile period or no juvenile period at all. In fact it almost appears to be the reverse of a juvenile period, with heightened sensitivity to very early cold exposure.

2. **Population Diversity –** Generating data on the bolting behavior of LX3632 required using large numbers of plants to cover the likely range of responses compared with carrots like Chantenay Red Cored. This is why growth cabinet studies were not pursued and all data comes from field plantings of large numbers of carrots.

3. **Cardinal Temperature Values** – There was the prospect that the actual temperatures for vernalization in Chantenay Red Cored, might be different to those in other carrot varieties, especially LX3632. Discussion with plant physiologists (Daniel Tan, Gordon Rogers *pers. comm*. April 2010) agreed the actual temperatures were not as likely to vary between cultivars of the same species, as the time requirement for exposure to temperatures in the vernalizing range i.e. different thermal times (°Cd values) for different varieties.

4. **Relevant Climatic Conditions** – Unlike seed growers and breeders, we are endeavouring to eliminate or at least minimise (early) bolting in commercial carrot crops. This means identifying the marginal periods for inducing early bolting were of most interest rather than the periods causing most severe bolting, so no studies were deliberately conducted with mid-winter plantings. In addition, even the coolest temperate growing regions in Australia were not found to have sufficiently low average daily temperatures to reach the theoretical optimum or sub-optimal vernalizing temperature range. The coldest month (July) on the north coast of Tasmania for example only gets down to an average daily temperature of 6.6-8.7°C. This meant the only temperature of any real interest or relevance was T_{max} and all the daily anomalies below this could be summed as thermal times (°Cd) to find a minimum value that triggered early bolting.

Materials & Methods

As this was effectively a meta-study, using all of the data from the LX3632 crops grown during, and in a few cases before the project, specific study materials and methods are not covered in this section. For more information on specific studies included in this section, please refer to the study index in Section 2 of the report.

Much of this section relies on large amounts of weather data being compiled and mathematically analysed. Individual site information has been assembled in Appendix 3 rather than included here.

The data in Appendix 3 shows sub 16°Cd anomalies for every day in the first 8 weeks of crop development.

Results & Discussion

***Table 3.2.1** – Cumulative Vernalizing °Cd for All LX3632 Black Carrot Studies in Project VG06135 using the Model developed by Craigon et al (1990)*

						Cumulative °Cd (X) Days After Planting							
No.	**Location**	**State**	**Crop ID**	**Planting Date**	**% Bolting before 20 weeks (140 Days)**	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**
BC0601	Nangilloc	Vic		04-Mar-06	<0.1	0.0	0.0	0.0	0.0	5.8	12.3	24.4	43.8
BC0700	Mersey Lee	Tas		14-Nov-06	30.00	18.0	28.1	45.7	53.1	68.3	79.9	86.9	87.9
BC0701	Robinvale	Vic	Planting 1	09-Feb-07	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3
BC0701	Robinvale	Vic	Planting 4	22-Feb-07	<0.1	0.0	0.0	0.0	0.0	0.2	0.3	0.7	0.7
BC0702	Bowen	Qld	Planting 1	02-May-07	<0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.2	3.6
BC0702	Bowen	Qld	Planting 2	25-May-07	<0.1	0.0	0.0	0.2	2.1	4.7	4.9	6.2	9.9
BC0702	Bowen	Qld	Planting 3	17-Jul-07	<0.1	2.8	2.8	3.0	3.0	3.0	3.0	3.0	3.0
BC0703	Katherine	NT	Planting 1	24-May-07	<0.1	0.0	0.0	0.2	0.5	0.5	1.8	3.2	3.3
BC0703	Katherine	NT	Planting 2	14-Jun-07	<0.1	0.3	0.3	1.7	3.1	3.1	3.1	3.1	3.1
BC0704	Darwin	NT	Planting 1	09-May-07	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BC0704	Darwin	NT	Planting 2	30-May-07	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BC0704	Darwin	NT	Planting 3	20-Jun-07	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BC0705	Clyde	Vic	Planting 1	26-Oct-07	27.00	2.9	13.6	15.3	19.7	20.7	20.7	24.6	25.1
BC0705	Clyde	Vic	Planting 2	29-Oct-07	22.00	7.1	14.0	15.3	20.7	20.7	20.7	25.1	26.6
BC0706	Clyde	Vic		08-Nov-07	15.00	2.4	4.4	7.9	7.9	11.8	12.3	16.7	16.7
BC0707	Parilla	SA	Planting 1	19-Sep-07	30.00	10.6	19.1	37.6	50.6	54.8	61.7	66.8	66.8
BC0801	Dareton	NSW		23-Jan-08	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BC0804	Dareton	NSW	Planting 1	19-Mar-08	<0.1	0.0	0.0	0.2	1.4	1.4	13.8	19.9	25.4
BC0804	Dareton	NSW	Planting 2	03-Apr-08	<0.1	0.2	1.4	1.4	16.7	20.3	25.4	40.0	52.2
BC0805	Parilla	SA	Planting 1	19-Nov-08	20.00	7.3	8.2	8.2	8.2	8.3	8.3	9.0	9.0
BC0805	Parilla	SA	Planting 2	10-Dec-08	6.00	0.0	0.1	0.1	0.8	0.8	0.8	0.8	0.8
BC0805	Parilla	SA	Planting 3	01-Jan-09	<0.1	0.6	0.6	0.6	0.6	0.6	2.0	2.0	2.0
BC0805	Parilla	SA	Planting 4	27-Jan-09	<0.1	0.0	0.0	1.4	1.4	1.4	1.9	3.4	3.8
BC0805	Parilla	SA	Planting 5	18-Feb-09	<0.1	0.0	0.7	0.7	0.7	2.1	15.5	22.0	25.5
BC0806	Parilla	SA	Planting 2	12-Feb-08	<0.1	0.0	0.0	0.7	0.7	0.7	2.1	16.4	22.0
BC0901	Clyde	Vic	Planting 2	03-Feb-09	<0.1	0.0	2.1	2.1	2.8	5.3	7.2	8.4	9.1
BC0902	Dareton	NSW		26-Jan-09	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BC0903	Dareton	NSW		23-Jan-09	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BC0905	Clyde	Vic		11-Feb-09	<0.1	0.9	1.3	1.6	4.1	6.9	7.5	7.9	16.4
BC0910	Tyabb	Vic		27-Nov-09	7.00	1.9	5.5	8.3	9.2	9.7	9.8	9.8	11.9

Significant EARLY Bolting – Defined as anything greater than trace levels (0.1%)

Outlier results – Conflict with general trend

21 & 28 day Cumulative °Cd used to formulate the critical values for LX3632

***Figure 3.2.2** Relationship between Accumulated Thermal Period (°Cd) & % Early Bolting **7** Days After Planting*

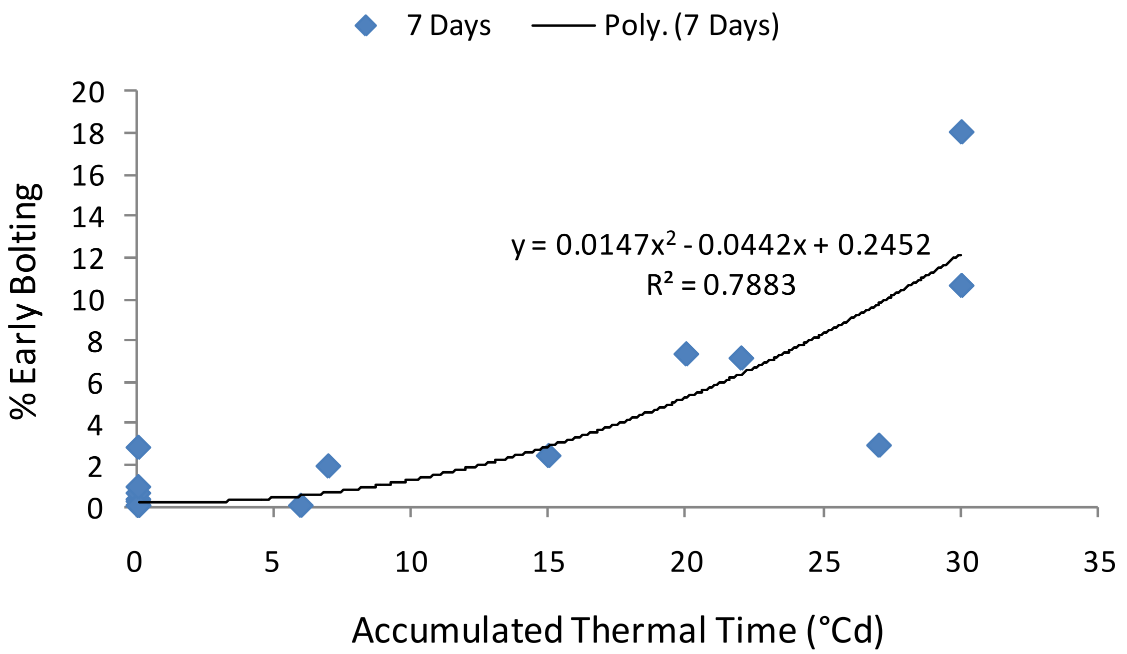


***Figure 3.2.3** Relationship between Accumulated Thermal Period (°Cd) & % Early Bolting **14** Days After Planting*

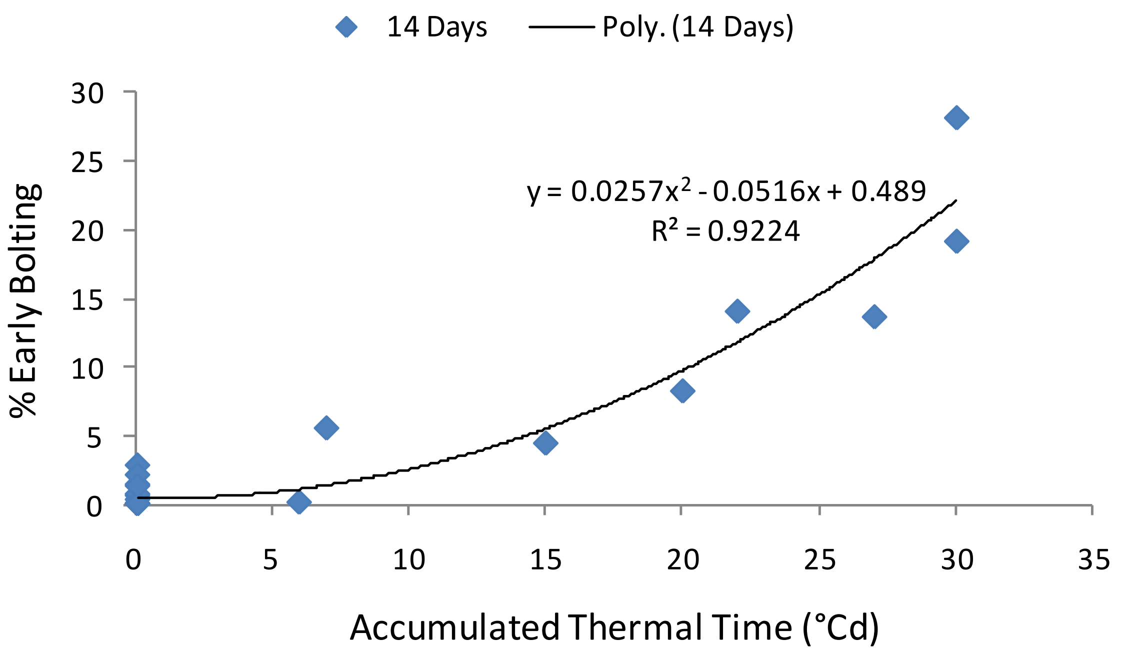


Figure 3.2.4 *Relationship between Accumulated Thermal Period (°Cd) & % Early Bolting* ***21*** *Days After Planting*

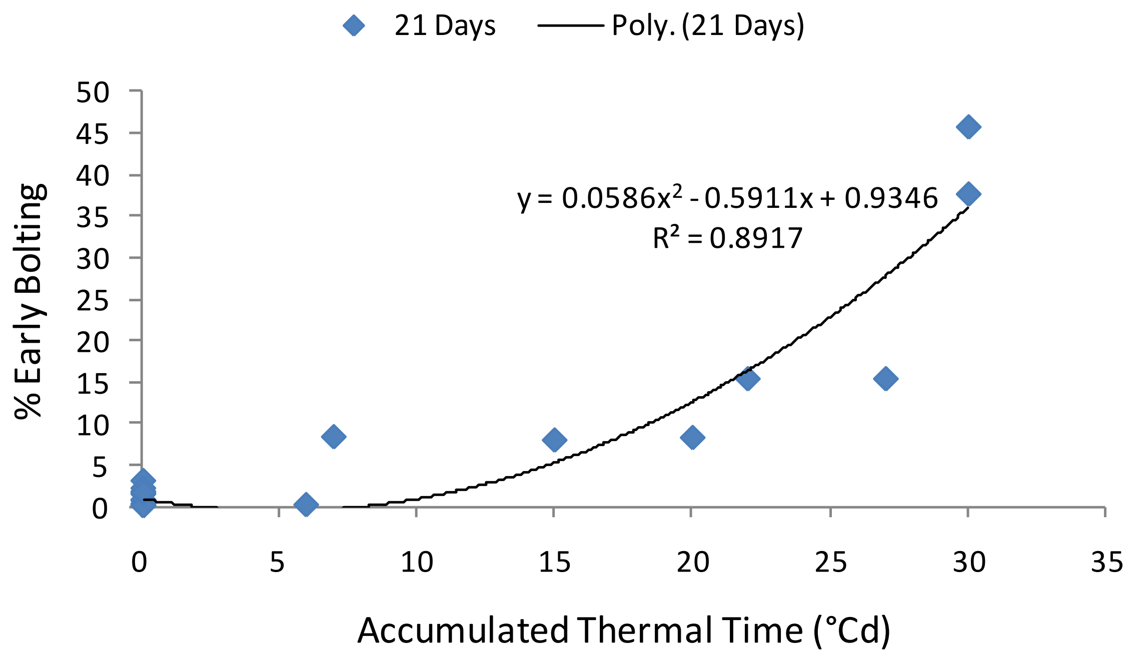


Figure 3.2.5 *Relationship between Accumulated Thermal Period (°Cd) & % Early Bolting* ***28*** *Days After Planting*

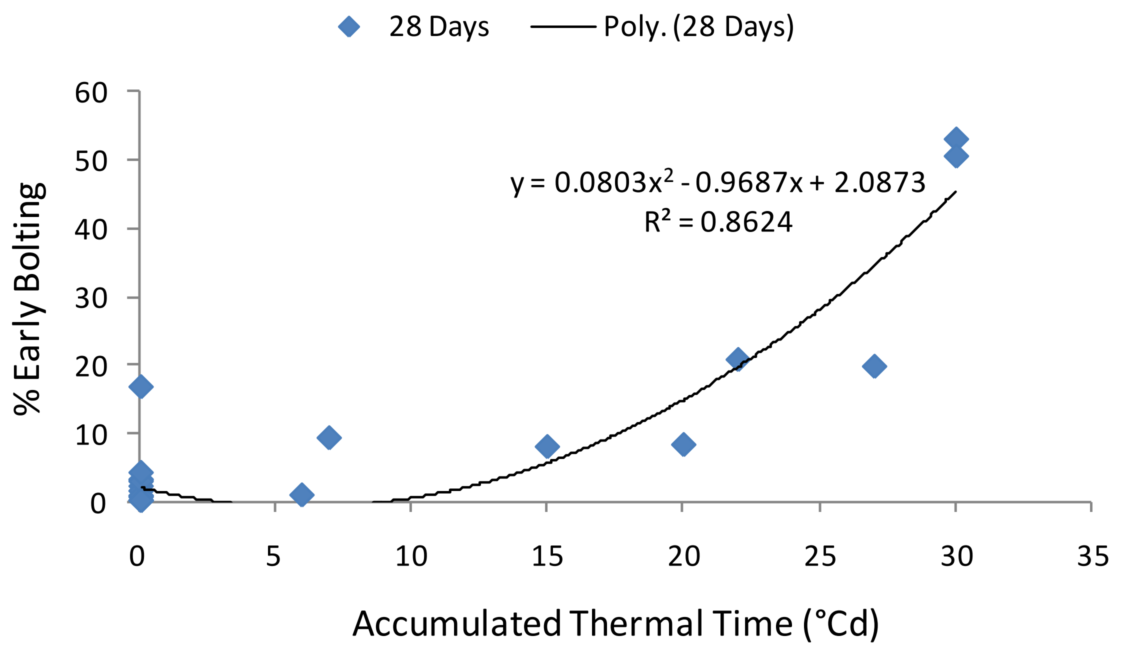


Figure 3.2.6 *Relationship between Accumulated Thermal Period (°Cd) & % Early Bolting* ***35*** *Days After Planting*

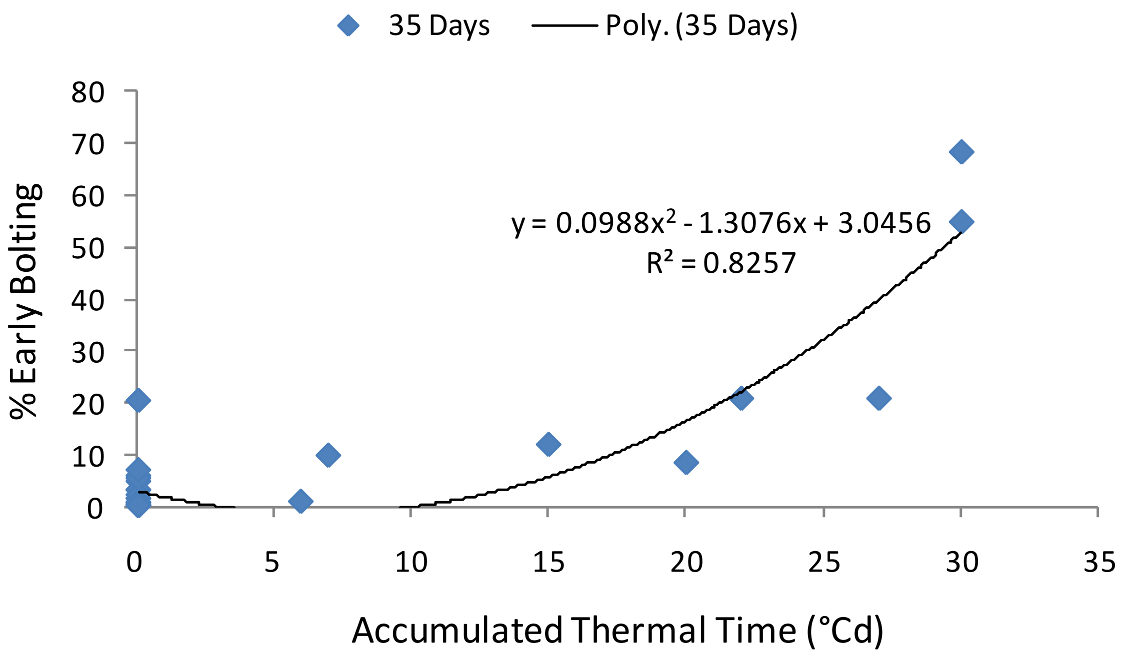


Figure 3.2.7 *Relationship between Accumulated Thermal Period (°Cd) & % Early Bolting* ***42*** *Days After Planting*

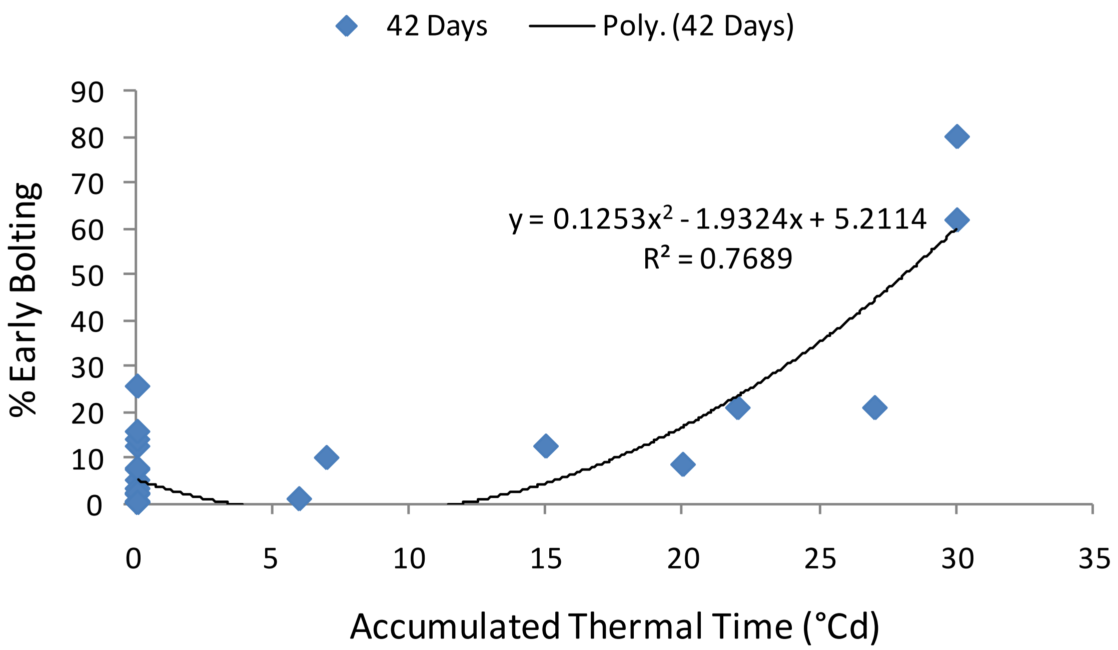


***Figure 3.2.8** Relationship between Accumulated Thermal Period (°Cd) & % Early Bolting **49** Days After Planting*

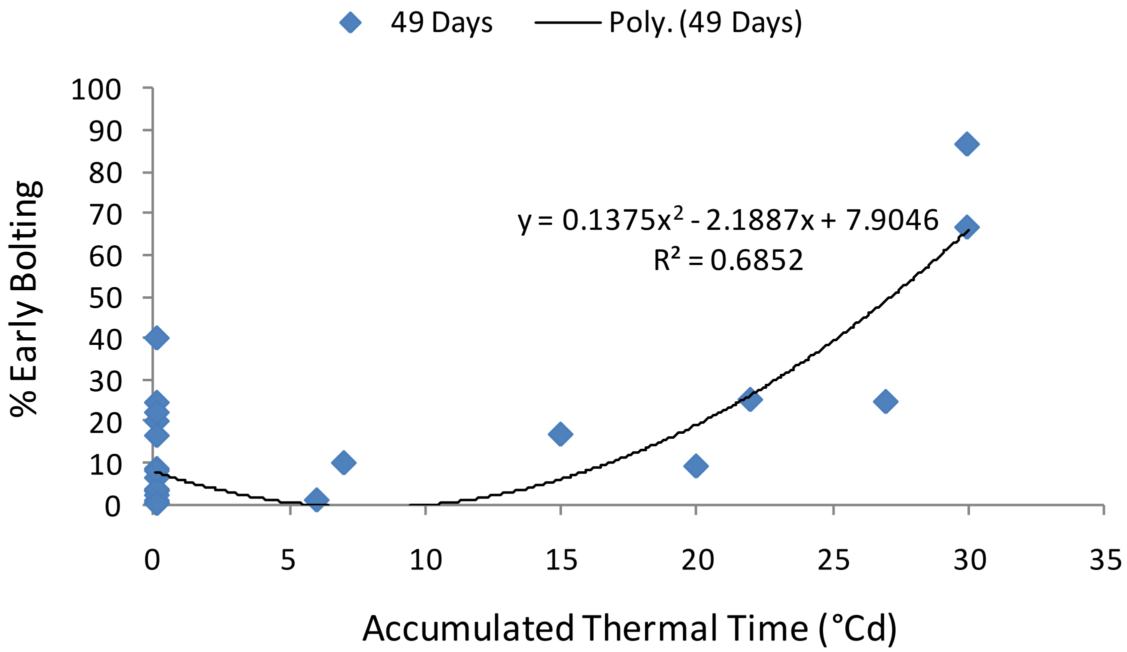


***Figure 3.2.9** Relationship between Accumulated Thermal Period (°Cd) & % Early Bolting **56** Days After Planting*

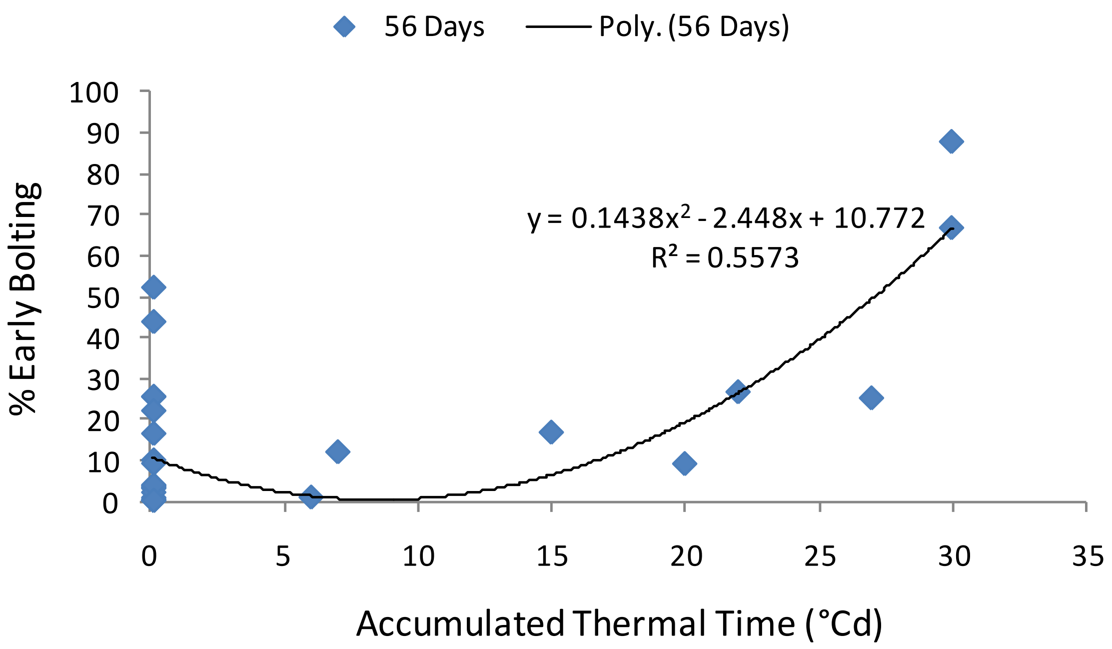


Photo 3.2.1 *BC0910 Tyabb, Vic – First carrots in a 27 Nov 2009 planting of LX3632 showing first showing signs of bolting only 40 days after planting (whole plant).*

Photo 3.2.2 *BC0910 Tyabb, Vic – First carrots in a 27 Nov 2009 planting of LX3632 showing first signs of bolting only 40 days after planting (close up of stem).*

Photo 3.2.3 *BC0910 Tyabb, Vic – View of crop* ***40*** *days after planting.*

Photo 3.2.4 *BC0910 Tyabb, Vic – View of crop* ***58*** *days after planting.*

Photo 3.2.5 *BC0910 Tyabb, Vic – Flowering LX3632 only **58** days after planting.*

First Signs of Early Bolting
Firstly to reiterate, all references are to EARLY bolting. Many of the crops showing negligible early bolting in fact went on to show high levels of late bolting after around 150 days.

Field observations of the earliest time clearly bolting carrots were found in LX3632 crops known to have been exposed to vernalizing temperatures was around 40 days after planting (BC0910 - Photos 3.2.1-3.2.3). Atherton *et al* (1990) found the shortest period from the end of ideal vernalization conditions to the appearance of an internode was around 27 days. If the same period applies to LX3632, this would indicate adequate vernalization in the first 13 days can be sufficient to induce flowering in LX3632. However, these were the youngest plants found in a population with varied responses, which indicates the sensitive window for induction of early bolting may extend for some time after this. The bulk of vernalizing plants in this same situation (BC0910 – Photos 3.2.4-3.2.5) appeared before 58 days.

Critical Vernalization Period for Early Bolting
These observations in conjunction with the climate data used in Table 3.2.1 suggested the most likely period to analyse for critical vernalizing° Cd was the first 3-4 weeks after planting.

On balance it would seem the first 3 weeks are more critical than the fourth week. This is best exemplified by BC0804 – planting 2. Nonetheless, given this is a "beta-test" model only, it would be safer for the time being, to extend the danger period by a week to reduce the probability of early bolting in determining planting dates.

Figures 3.2.2-3.2.9 show % early bolting as a function of weekly accumulated thermal times and a polynomial trend-line. The most interesting thing about these figures as a group is the that best correlations between thermal times and % bolting was at 14 days (R^2=0.92). This was followed closely by 21 days (R^2=0.89) then 28 days (R^2=0.86). The correlation then continued to diminish which is consistent that the critical period for vernalization leading to early bolting is immediately after sowing.

Key Results
The data shows that LX3632 will tolerate very little exposure to average day temperatures <16°C in the first 2-4 weeks after planting. Even without the aid of the model used, planning the seeding time for a crop should be based on excluding the possibility of any average day temperatures being <16°C in the first 4 weeks after planting.

In the first 14 days after planting, the minimum requirement for early bolting indicated was 2.9-4.4°Cd (ignoring a single outlier result – see below).

In the first 21 days after planting, the minimum requirement for early bolting indicated was 3.1-7.9°Cd.

In the first 28 days after planting, the minimum requirement for early bolting indicated was 4.2-7.9°Cd (ignoring a single outlier result – see below).

The critical period for vernalization leading to early bolting is unlikely to extend much beyond the first 28 days after planting based on two key factors:

1. First clearly bolting plants can occur in under 40 days after planting. There is a minimum time interval required between end of vernalization and first visual signs of bolting.
2. In 5 cases (including one of the outlier results) a marked increase in accumulated °Cd after 4 weeks did not result in early bolting.

Heat Unit Accumulation for Vegetative Plant Development
Caution is recommended in southern regions for late summer plantings of all carrots, not just LX3632 which behaves the same way.

This follows a further complication to establishing safe windows for sowing in southern climates, which relates to whether the intended time falls towards the beginning or the end of the "safe" window.

Bolting aside, this was an issue seen in all southern crops, not just black carrots. The problem seen was that under cooling conditions (autumn), late sown crops may well avoid early bolting from adequate warmth in the first 3-4 weeks but suddenly experience rapidly cooling weather which had the effect of stunting all vegetative growth.

Late sown (eg. March in Parilla) ordinary carrots like Red Hot or Apache were never seen to produce high yielding crops. Plants remained stunted all winter, putting on very little vegetative growth (carrots or canopy) compared with plantings made only one or several weeks earlier. This meant that in spring, crops would again start to grow but also begin to LATE bolt at the same time, having experienced sufficient vernalizing° Cd (even Red Hot or Apache). This is an area worthy of further research but was beyond the scope of the current project.

Outliers

BC0805 Planting 2
Of the 30 sites included, this is the only site that showed significant bolting in the apparent absence of exposure to less 7.9-8.2° Cd in the first 3 weeks.

The most difficult to explain result is for BC0805 planting 2. The reference BOM weather station for Lameroo shows very little cold exposure any time in the first 8 weeks, yet the level of bolting sits neatly between greater bolting in the planting made 21 days earlier and no bolting in the planting made 22 days later. In fact the exposure to cold in the first 3 weeks was greater in planting 3 than in planting 2.

Planting 2 was a small hand planted area made immediately adjacent to planting 1 (same bed with no crop separation) which bolted severely. If bolting is indirectly related to cold exposure rather than directly, for example cold stimulated the production of a phytochemical released by carrots to stimulate adjacent plants to also flower, this may explain this observation. It is possible also that localized cooling, particularly if there was no wind overnight at Parilla, did not registered at the Lameroo BOM site.

It is also worth noting that 6% bolting was the lowest level of significant early bolting seen at any of the 30 sites used. Early bolting tended to either occur at frequencies of <0.1% or greater than 10%, indicating a sharp change in the vernalization response over a tight accumulated °Cd range.

BC0804
This was the latest planting made and was only a small hand planted area deliberately sown to observe bolting effects. The weather data is known to be accurate as it was collected on site rather than from the nearest BOM site. What the result strongly suggests is that exposure in the first 3 rather than 4 weeks is critical in determining early bolting.

If this is indeed the case, the result is not an outlier at all. For simplicity we have accumulated °Cd over a set period and made the assumption any day in that period is approximately equivalent. However, it may well be that even within this 3 week period, the earlier the exposure to cold, the greater the likelihood of inducing bolting.

4 Optimum Planting Densities for Black Carrots

Introduction

Observations of crops prior to this project showed a high variance in individual plant size, with an undesirably high proportion of smaller carrots. In standard modern orange carrot lines such as Red Hot, individual plants show a strong ability to make use of any available space adjacent to them. Where alongside a healthy plant, another plant dies or fails to germinate, or an unusually wide space develops, Red Hot carrots will typically grow to exceed the population size average. It was hoped that black carrots might behave in the same way, given the opportunity, and a higher average weight might be achieved, while maintaining a high total yield/ha.

To test this, a trial (BC0705) was established using a variety of plant spacings, ranging from slightly closer than normal, to markedly further apart than usual. The reference for “normal” was standard Apache/Red Hot spacings. In consultation with Excel Fresh, SDS & several key growers this was established to be very close to 30 mm.

Subsequent to the findings of the main trial, two follow up studies (BC0808 & BC0905) were conducted to investigate the potential of black carrots to self-thin. The purpose of this was to address situations where seed quality may have suffered and growers might be able to counter this by using unusually high seeding rates to achieve good plant establishment.

Key Outcomes

For the Excel Fresh variety LX3632, a 10/40/10 configuration (see Section 2 – General Materials and Methods), on 1.63 metre centred beds:

- Based on all trials, a 40-**50**mm plant spacing (with a preference towards the wider end of this range) appears to be the ideal plant spacing for this variety balancing yield and average carrot size.

- 30-35mm spacings between plants (~714,000–833,000 plants/ha) achieved the highest yield of harvestable carrots, using either a 21 or 26 mm minimum shoulder (crown) width. However, the average weight of harvestable carrots was low (74-81 g at 21 mm minimum width and 87-95 g at 26 mm minimum width).

- **50 mm spacings** between plants (500,000 plants/ha) achieved a higher average harvestable carrot weight of 100 g at 21 mm and 111 g at 26 mm. The yield trade-off required to achieve this was not significant.

- Plant density significantly affected the population frequency of bolting, with significantly higher levels of bolting at lower plant densities.

These densities are likely to apply to other row and bed configurations, particularly the 7/27/7/27/7 configuration using 3 paired rows on 1.6 metre bed centres.

These figures should help a processor make decisions that balance the trade-off between yield and average carrots size (weights) and through this, recommendations to growers about the preferred establishment density.

<u>Important Note</u>: The above figures refer to targeted plant establishment densities NOT seeding densities which will be higher and vary with seed viability and survival in the field.

Using very high <u>seeding</u> densities (resulting in plant spacings less than 25 mm) to overcome poor seed viability was not found to be useful. While total yields were high, harvestable yields were very poor and stands did not self-thin to the extent required to counter over-rate sowing.

Manipulating plant density was not found to be a useful way of controlling canopy vigour. Although the canopy/carrot weight ratio increased as plant spacing increased, the change was small and carrot yield alone was a much more important consideration. Larger carrots were associated with larger tops and higher yields of carrots were associated with higher canopy weights.

Plant density did not significantly affect pH, Brix or anthocyanin content per unit weight of harvested material.

Materials & Methods (BC0705 – Clyde, Vic, 2007-08)

This was the main trial used to obtain ideal plant spacing recommendations.

Location:

This trial was located near Clyde (approx: 38° 09′ 05″ S, 145° 20′ 38″ E) inside a dedicated bay separate from commercial bunching vegetable crops (Dutch Carrots, Bok-Choy, Bunching onions etc), on very light sandy black soil, typical of the region.

Design:

Plots (Varieties) were replicated four times in randomised complete blocks. Plots consisted of two pair-planted rows (4 single rows in total) on a single bed 1.63 m wide (bed centre to adjacent bed centre), 2.0 metres long.

Soil testing prior to planting showed ideal nutrient status for carrots with no deficiencies. No fertilizer or chemicals were applied.

Beds were formed several days before planting. All seed was hand planted on 26 Oct 2007 (replicates 3 & 4) and 29 Oct 2007 (replicates 1 & 2), to a depth of about 5-10 mm by marking lines for rows, creating a shallow furrow with a vee-shaped aluminium tine. Plots were then seeded by hand, by dropping 3-4+ seeds at designated spacings (see treatment list). Furrows were then lightly covered by hand.

Seedlings were thinned by hand on 03 Dec 2007, to a single plant at each planting point, with care taken not to deliberately select healthier or weaker plants.

Irrigation was provided by solid set sprinklers arranged in a square grid pattern with 10 metres between risers. Irrigation intervals were determined by the grower and scheduled as for the rest of the farm, typically a single application of 6 mm/day at the beginning to a 8-10 mm/day during the hottest parts of summer.

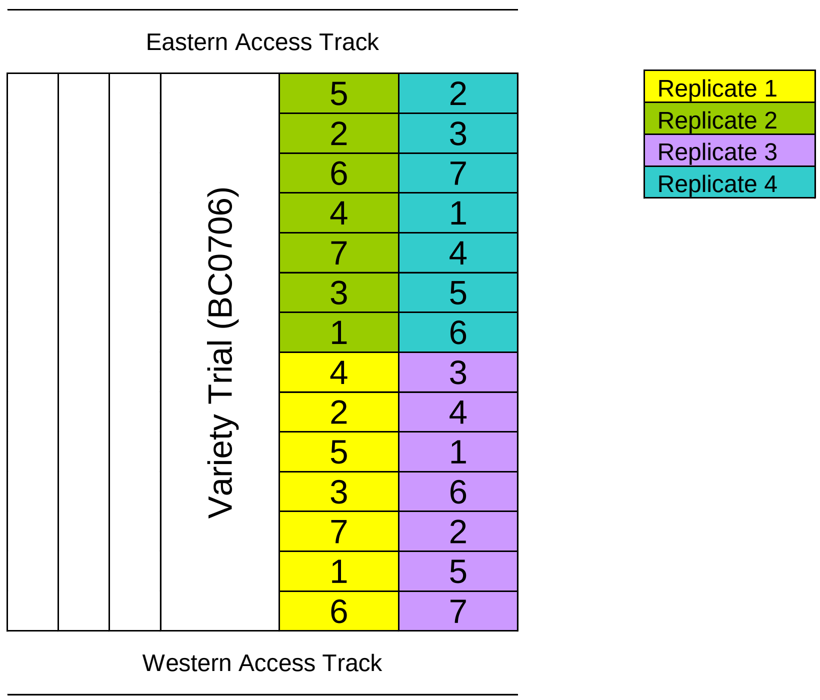
No fungicides or herbicides were applied and all weeding was done by hand.

Table 4.1 *– BC0705: Treatment (plant density) Details*

Treatment	Plant Spacing (mm)	Plants/m of row	Plants/m of bed	Plants (seeds)/ha
1	**25**	40.00	160.00	1,000,000
2	**30**	33.33	133.33	833,313
3	**35**	28.57	114.29	714,313
4	**40**	25.00	100.00	625,000
5	**50**	20.00	80.00	500,000
6	**75**	13.33	53.33	333,313
7	**100**	10.00	40.00	250,000

Seed Treatment as supplied; usually Thiram & Iprodione at “standard” rates. Apron XL & Maxim XL were also applied at above rates yields at total loading of 74 mg metalaxyl-m + 5 mg fludioxonil per 100 g of seed. These were not registered for use in carrots in Australia at the time the trial was conducted but were used to reduce the impacts likely to be caused by damping off pathogens.

Figure 4.1 *– BC0705: Trial layout*



Evaluation:

Photographs were taken at various stages between emergence and harvest. Bolting was assessed 08 Jan 2008 (71 & 74 DAP). Harvest assessments were carried out on four separate dates, with one whole replicate harvested on that date (115, 120, 134 & 151 DAP) by harvesting 1.00m of bed (all 4 carrot rows) and assessing bolting, carrot numbers, weights, cracking and deformities. After taking photographs of whole samples, entire plot yields were packed in plastic bags and sent by overnight road transport to SDS Beverages in Merbein. Here they were cool stored for a several weeks at 4° C, before being juiced. A 500 mL sample of juice was kept from each sample, frozen and subsequently analysed in SDS's Merbein laboratory for Brix using a refractometer and anthocyanin content using an absorbance spectrophotometer.

<u>Statistical Analyses</u>:
In all tables shown, vertical bars aligned in the same column indicate means that are NOT SIGNIFICANTLY DIFFERENT (LSD, P=0.05). Means followed by "-" failed Bartlett's Chi-squared Test for Homogeneity of Variance and attempts to rectify this with transformations were NOT successful (P=0.05). NSAP indicates no statistical analysis performed. Blue vertical bars indicate LSD results based on successfully transformed data BUT the numbers they follow are original.

Results (BC0705 – Clyde, Vic, 2007-08)

Table 4.2. *BC0705: Carrot Yield Components – Raw Data (t/ha), classified by Plant Spacing (mm)*

Plant Spacing (mm)	TOTAL Yield - Carrots NOT BOLTING (t/ha)	Plant Spacing (mm)	YIELD 21+mm - Carrots NOT BOLTING (t/ha)	Plant Spacing (mm)	YIELD 26+mm - Carrots NOT BOLTING (t/ha)
30	45.878 I	**30**	44.517 I	**30**	38.936 I
25	45.558 I I	**25**	42.630 I	**25**	36.989 I
35	41.189 I I	**35**	40.231 I I	**35**	35.845 I
40	38.025 I I	**40**	37.183 I I	**40**	34.431 I
50	32.925 I	**50**	32.639 I	**50**	30.731 I I
75	23.141 I	**75**	23.097 I	**75**	22.464 I I
100	20.738 I	**100**	20.597 I	**100**	20.419 I

Table 4.3. *BC0705: Carrot Yield Components – Bolting Adjusted Data (kg/ha), classified by Plant Spacing (mm)*

Plant Spacing (mm)	TOTAL Yield - Carrots BOLTING ADJUSTED (t/ha)	Plant Spacing (mm)	YIELD 21+mm - Carrots BOLTING ADJUSTED (t/ha)	Plant Spacing (mm)	YIELD 26+mm - Carrots BOLTING ADJUSTED (t/ha)
30	51.530 I	**30**	49.990 I	**35**	44.223 I
25	51.395 I	**35**	49.648 I	**30**	43.658 I
35	50.825 I	**25**	48.061 I	**50**	43.249 I
50	46.210 I I	**50**	45.791 I I	**25**	41.602 I
40	45.949 I I	**40**	44.919 I I	**40**	41.601 I
75	39.048 I I	**75**	38.973 I I	**75**	37.909 I
100	34.629 I	**100**	34.382 I	**100**	34.082 I

Table 4.4. *BC0705: Average Carrot Weight (g), Harvestable Carrot Weights 21+ & 26+ mm (g) & Crown Width (mm), classified by Plant Spacing (mm)*

Plant Spacing (mm)	Average Carrot Weight (g)	Plant Spacing (mm)	Average Carrot Weight 21+ mm (g)	Plant Spacing (mm)	Average Carrot Weight 26+ mm (g)	Plant Spacing (mm)	Average Crown Width (mm)
100	138 I	**100**	150 I	**100**	155 -	**100**	40.8 I
75	123 I	**75**	127 I	**75**	139 -	**75**	38.4 I
50	94 I	**50**	100 I	**50**	111 -	**50**	34.1 I
40	74 I	**40**	83 I I	**40**	93 -	**40**	31.0 I I
35	73 I	**35**	81 I	**35**	95 -	**35**	30.4 I
30	66 I I	**30**	74 I	**30**	87 -	**30**	29.6 I I
25	58 I	**25**	72 I	**25**	86 -	**25**	26.9 I

Table 4.5. *BC0705: Total Top Weight, Bolting Adjusted Top Weight (kg/ha) & Average Top Weight (g), classified by Plant Spacing (mm)*

Plant Spacing (mm)	Total Top Weight (t/ha)	Plant Spacing (mm)	Bolting Adjusted Total Top Weight (t/ha)	Plant Spacing (mm)	Average Top Weight (g)
30	29.416 I	**30**	33.032 I	**100**	97.5 I
25	28.122 I I	**25**	31.935 I	**75**	79.9 I I
35	24.988 I I	**35**	30.944 I	**50**	61.3 I I
50	21.413 I I	**50**	30.124 I	**35**	44.4 I I
40	21.292 I I	**40**	26.322 I	**40**	42.9 I I
75	15.109 I	**75**	25.601 I	**30**	42.3 I I
100	14.670 I	**100**	24.357 I	**25**	35.8 I

Table 4.6. *BC0705: % Bolting at 71-74 DAP & Harvest & Canopy/Carrot Ratio, classified by Plant Spacing (mm)*

Plant Spacing (mm)	% Bolting 71-74 DAP	Plant Spacing (mm)	% Bolting at Harvest	Plant Spacing (mm)	Canopy/Carrot Ratio
30	5.6 I	**30**	11.1 I	**100**	0.74 I
25	5.9 I	**25**	11.7 I	**75**	0.67 I
35	8.8 I I	**40**	17.3 I	**50**	0.66 I
40	9.9 I I	**35**	19.1 I	**30**	0.65 I
50	12.0 I	**50**	28.7 I	**35**	0.63 I
100	24.0 I	**100**	40.0 I	**25**	0.63 I
75	24.2 I	**75**	40.8 I	**40**	0.58 I

Table 4.7. *BC0705: Brix, Absorbance & Anthocyanin Content at Harvest, classified by Plant Spacing (mm)*

Plant Spacing (mm)	Brix (°Br)	Plant Spacing (mm)	Absorbance (at 538 nm and 8.0° Brix)	Plant Spacing (mm)	Anthocyanin Content (mg/100 mL)
75	10.63 I	**35**	0.502 I	**35**	51.5 I
100	9.53 I	**100**	0.455 I I	**100**	46.8 I I
35	9.03 I	**50**	0.442 I I	**50**	45.5 I I
50	8.65 I	**30**	0.430 I I	**30**	44.2 I I
30	8.33 I	**25**	0.259 I I	**25**	26.6 I I
40	8.10 I	**75**	0.235 I	**75**	24.2 I
25	7.63 I	**40**	0.193 I	**40**	19.9 I

Table 4.8. *BC0705: % Forking, % Cracking & % Carrots with Enlarged Fibrous Roots at Harvest, classified by Plant Spacing (mm)*

Plant Spacing (mm)	**% Forked Carrots**	**Plant Spacing (mm)**	**% Cracked Carrots**	**Plant Spacing (mm)**	**% Carrots with Enlarged Fibrous Roots**
40	3.19 I	**30**	2.27 I	**25**	4.13 I
35	6.07 I	**50**	2.83 I	**35**	5.24 I
30	6.50 I	**75**	3.26 I	**40**	5.34 I
25	6.55 I	**25**	4.04 I	**30**	6.81 I
50	9.27 I I	**35**	4.79 I	**50**	7.31 I
75	16.90 I I	**100**	14.81 I	**100**	14.31 I
100	21.20 I	**40**	22.11 I	**75**	16.88 I
Transformation	None	Transformation	Arcsine Sqrt	Transformation	None

Figure 4.2. *BC0705: Carrot Yield Components – Adjusted for Bolting at different Plant Spacings (mm), classified by Plant Spacing (mm)*

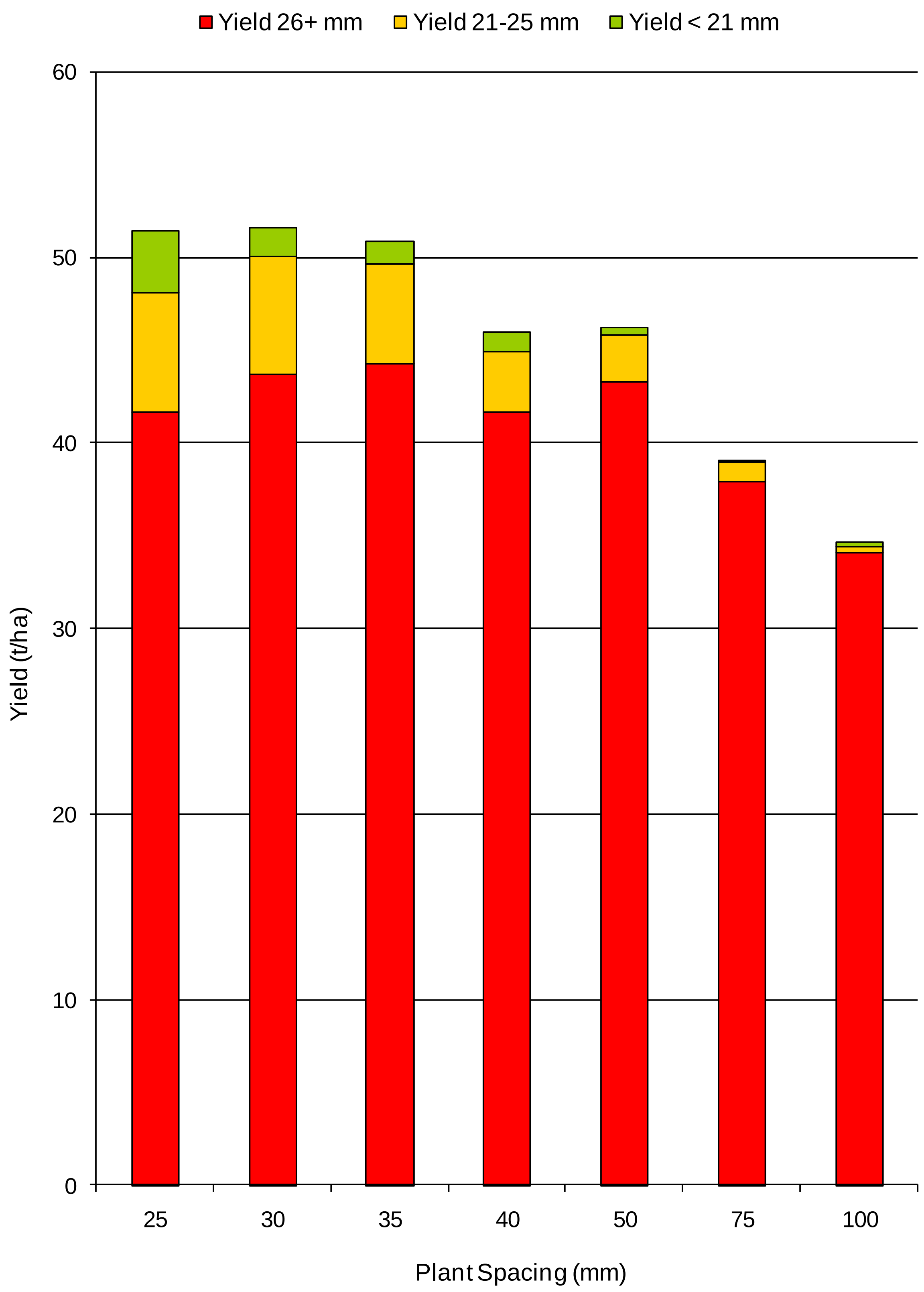


Figure 4.3. *BC0705: Average Carrot Weight (g), classified by Plant Spacing (mm)*

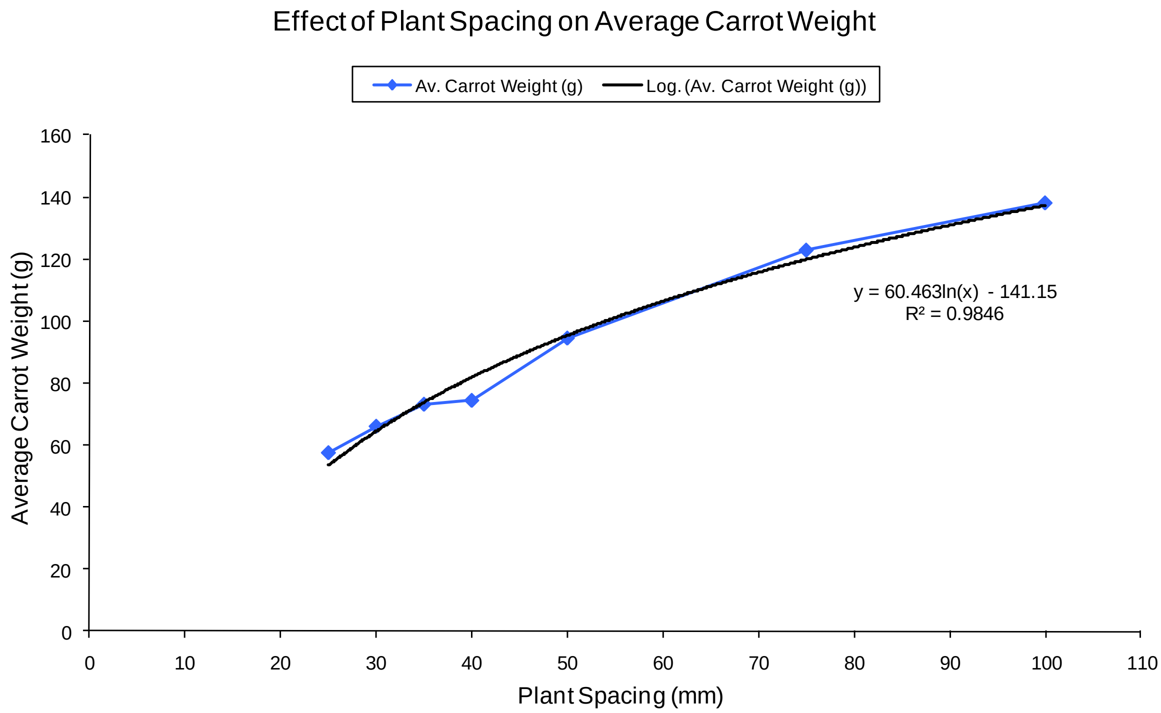


Figure 4.4. *BC0705: Average Carrot Crown Width (mm), classified by Plant Spacing (mm)*

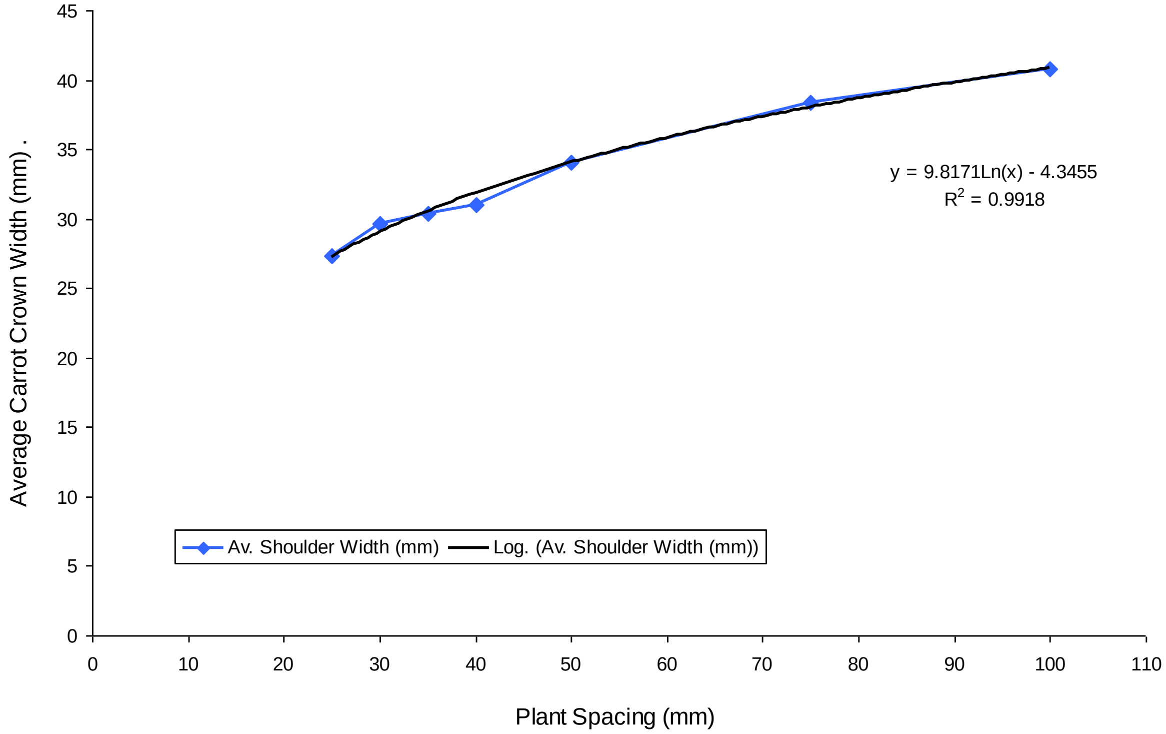


Figure 4.5. *BC0705: Top Weight: Carrot Weight Ratio, classified by Plant Spacing (mm)*

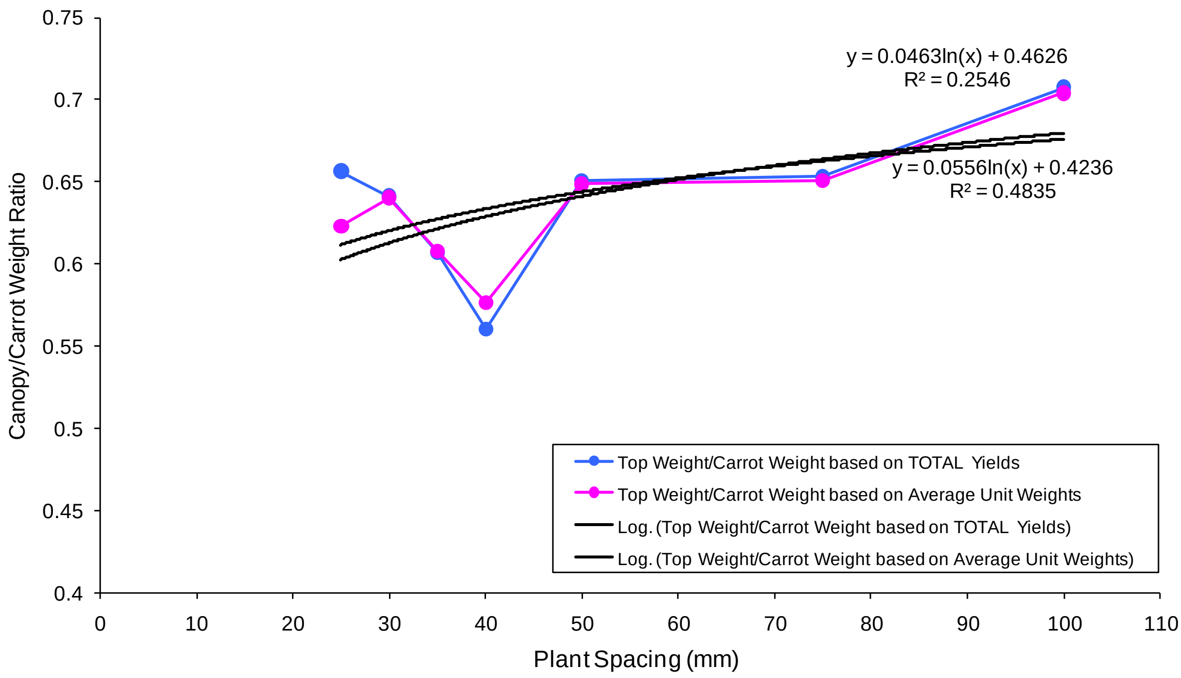


Figure 4.6. *BC0705: Individual Plants from Replicate 3 only – Carrot & Top Weights at **25 mm** Plant Spacings*

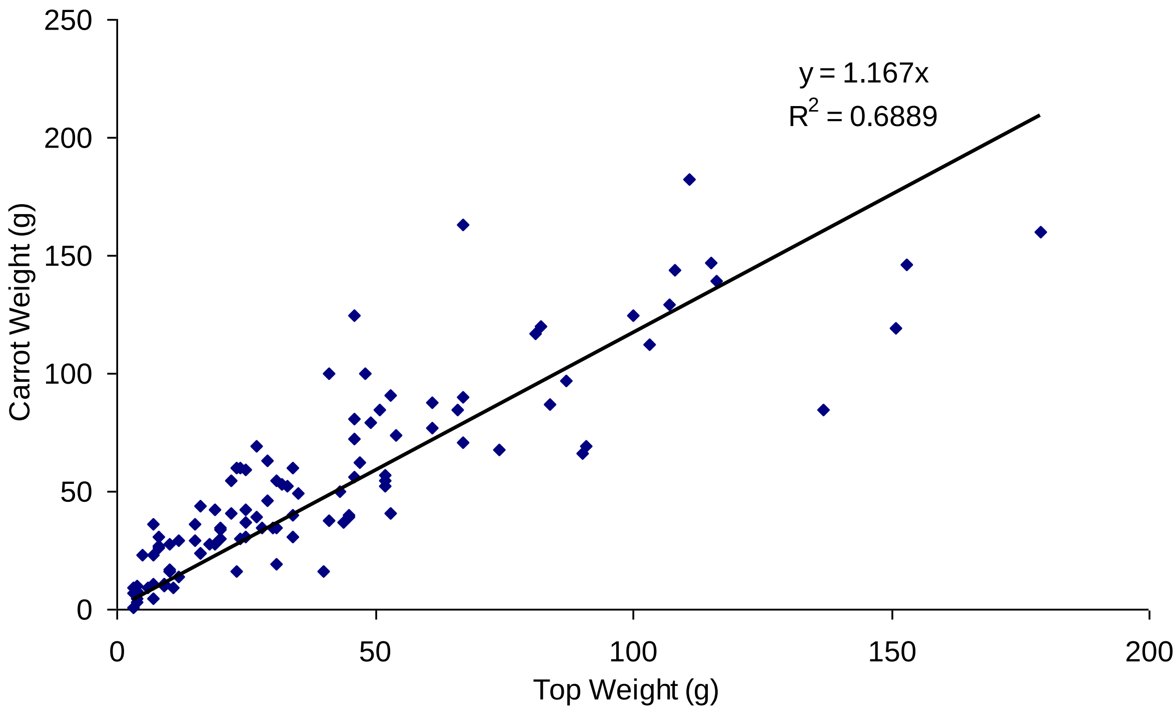


Figure 4.7. *BC0705: Individual Plants from Replicate 3 only – Carrot & Top Weights at* ***30 mm*** *Plant Spacings*

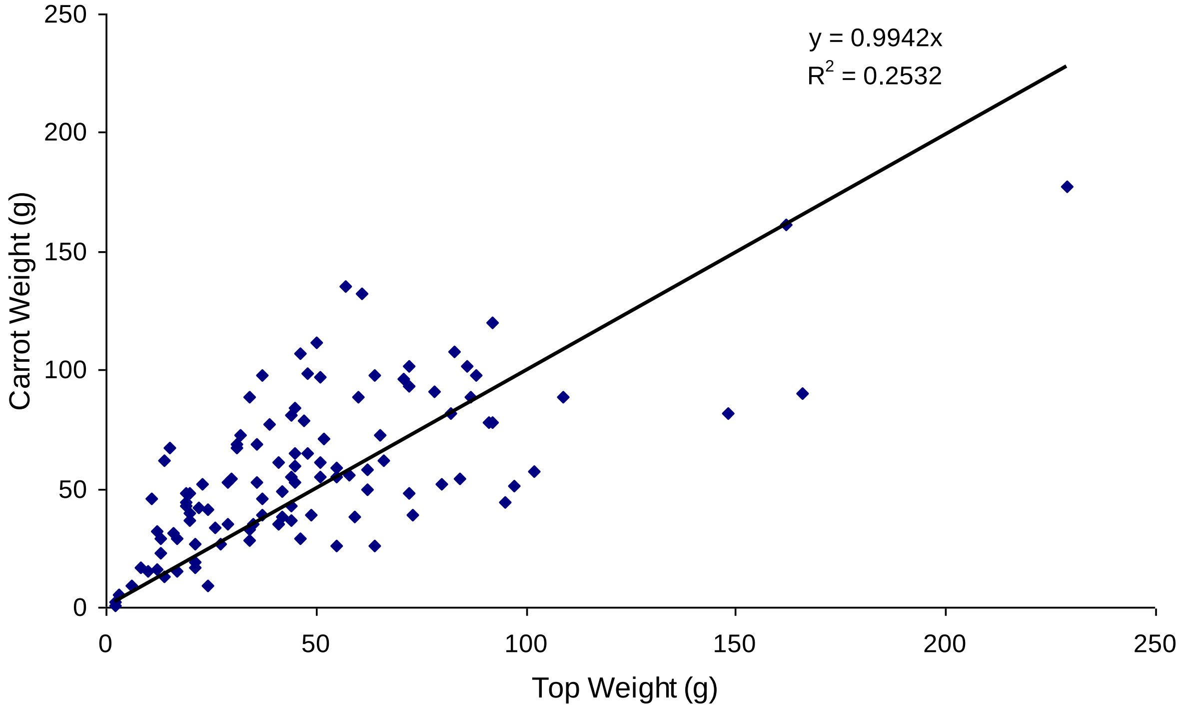


Figure 4.8. *BC0705: Individual Plants from Replicate 3 only – Carrot & Top Weights at* ***35 mm*** *Plant Spacings*

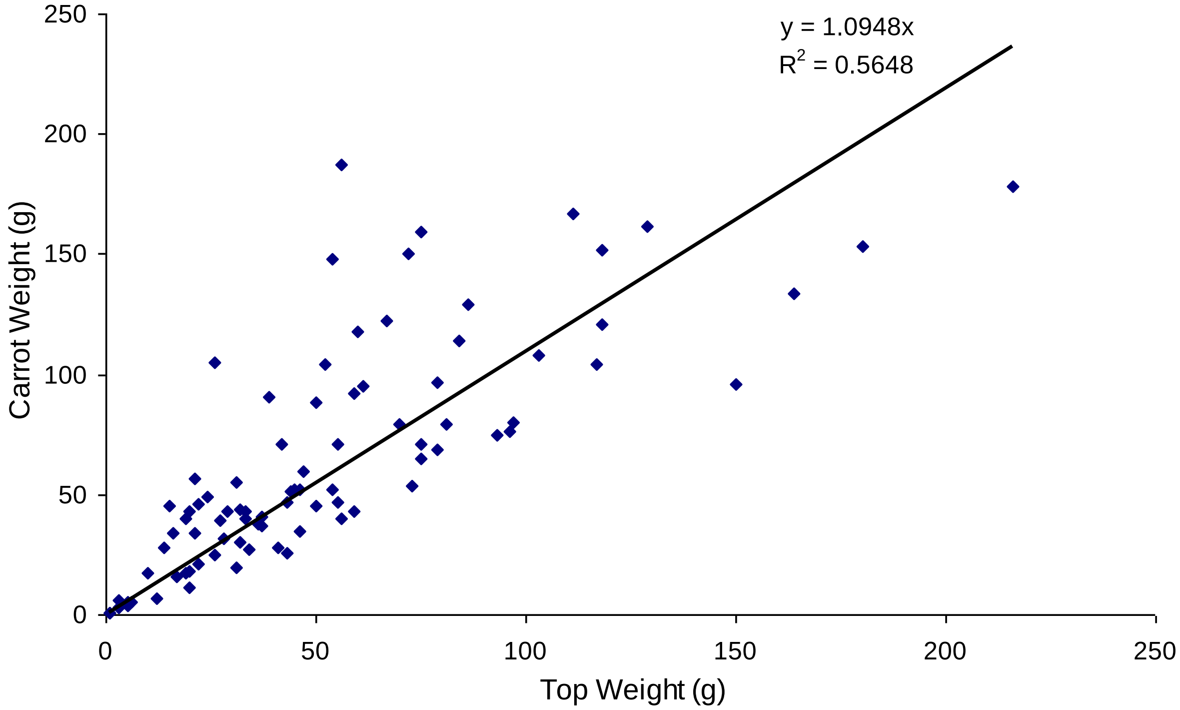


Figure 4.9. *BC0705: Individual Plants from Replicate 3 only – Carrot & Top Weights at **40 mm** Plant Spacings*

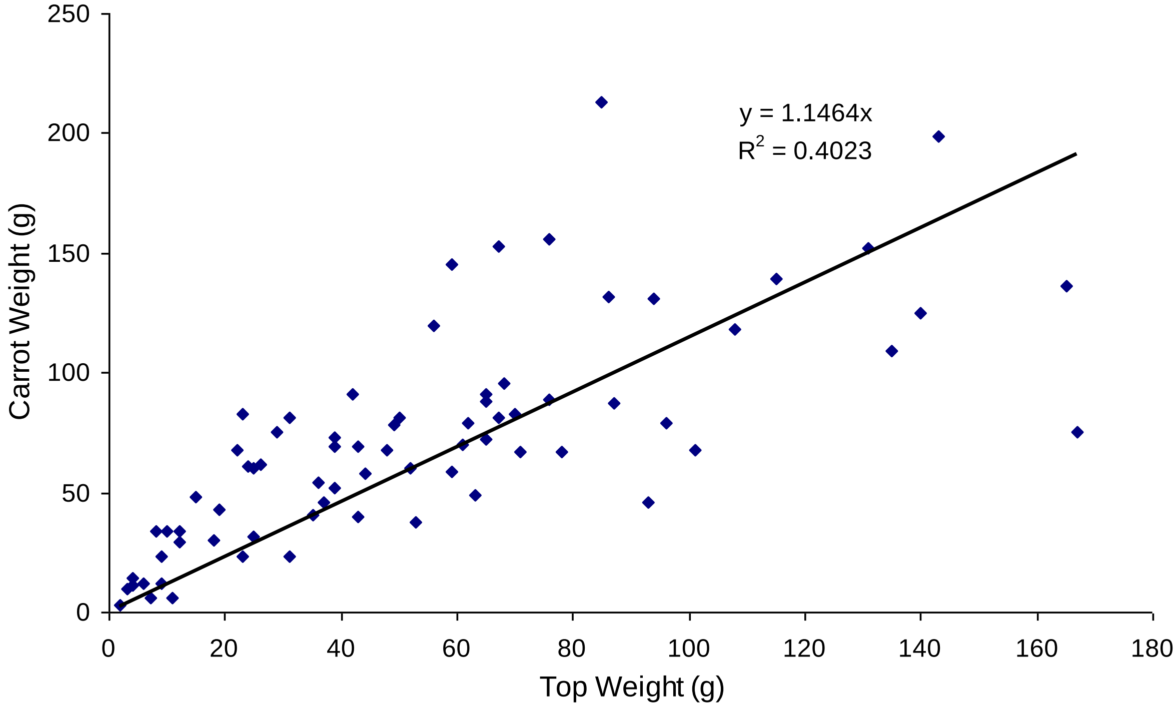


Figure 4.10. *BC0705: Individual Plants from Replicate 3 only – Carrot & Top Weights at **50 mm** Plant Spacings*

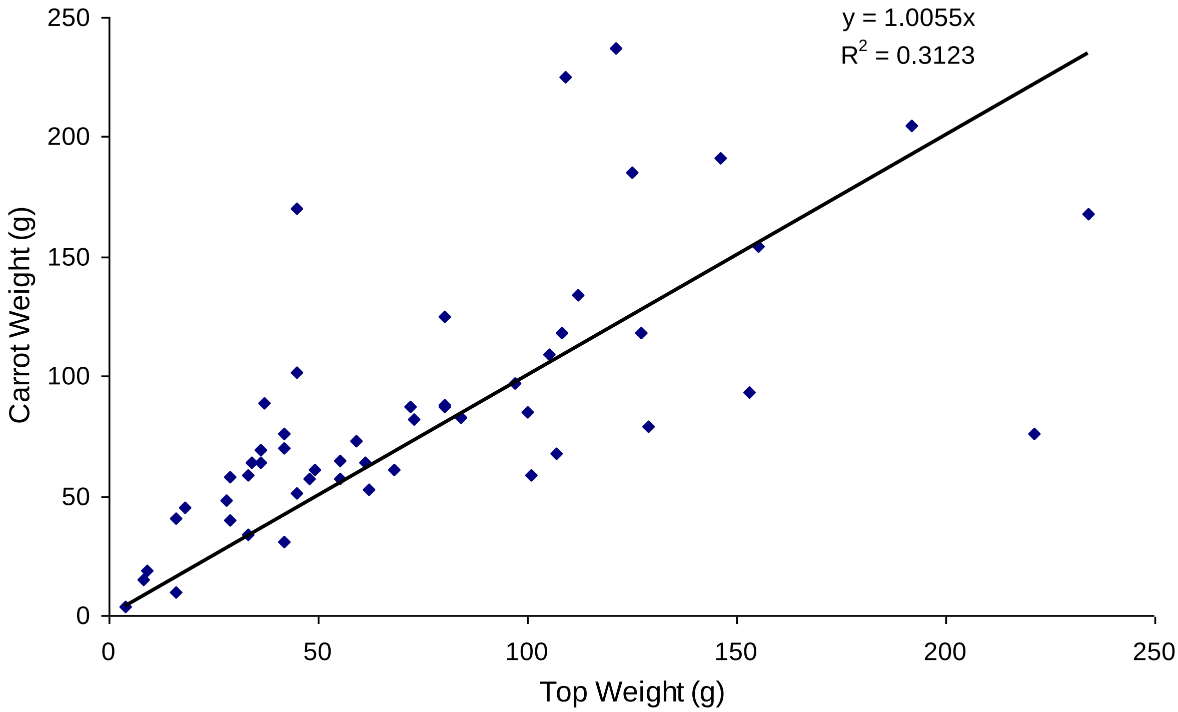


Figure 4.11. *BC0705: Individual Plants from Replicate 3 only – Carrot & Top Weights at* ***75 mm*** *Plant Spacings*

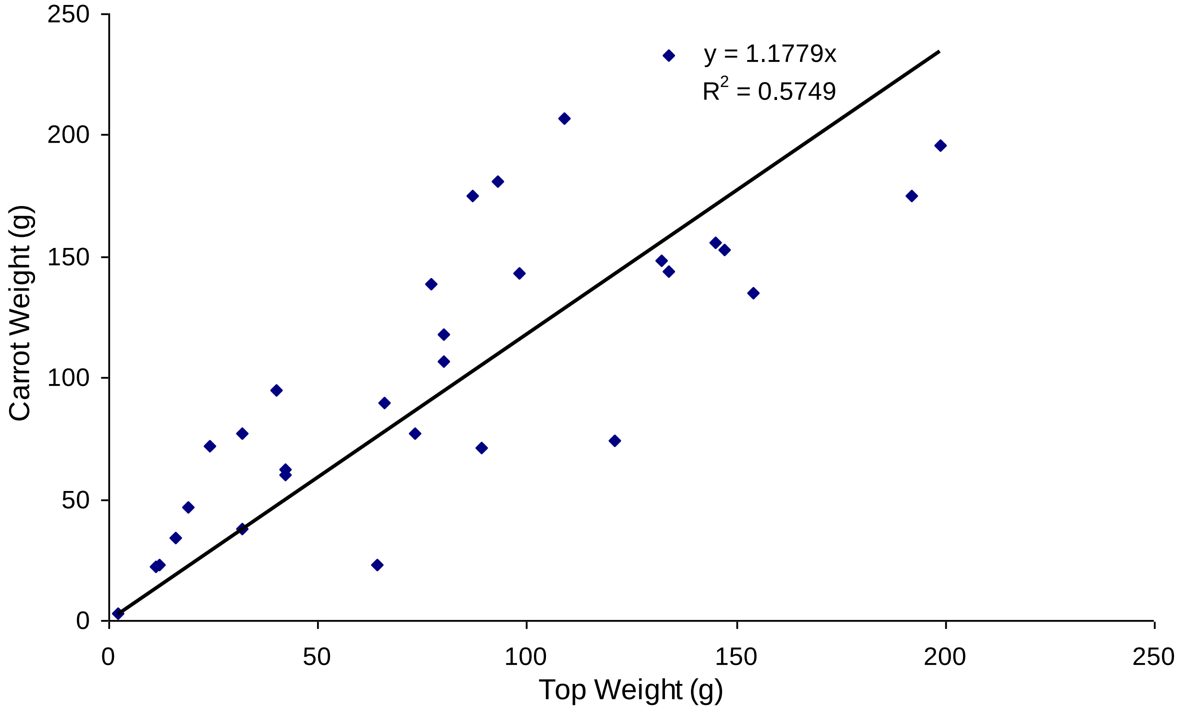


Figure 4.12. *BC0705: Individual Plants from Replicate 3 only – Carrot & Top Weights at* ***100 mm*** *Plant Spacings*

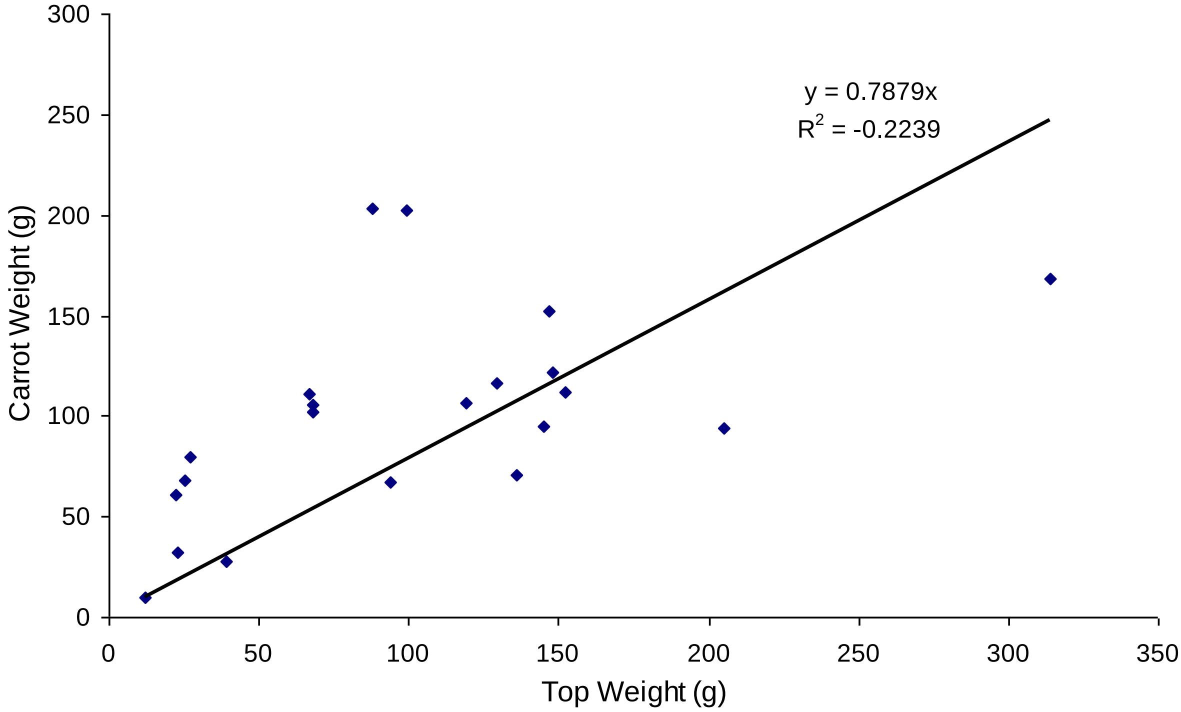


Figure 4.13. *BC0705: Individual Plants from Replicate 3 only – Carrot & Top Weights at **25-100 mm** Plant Spacings (All treatments)*

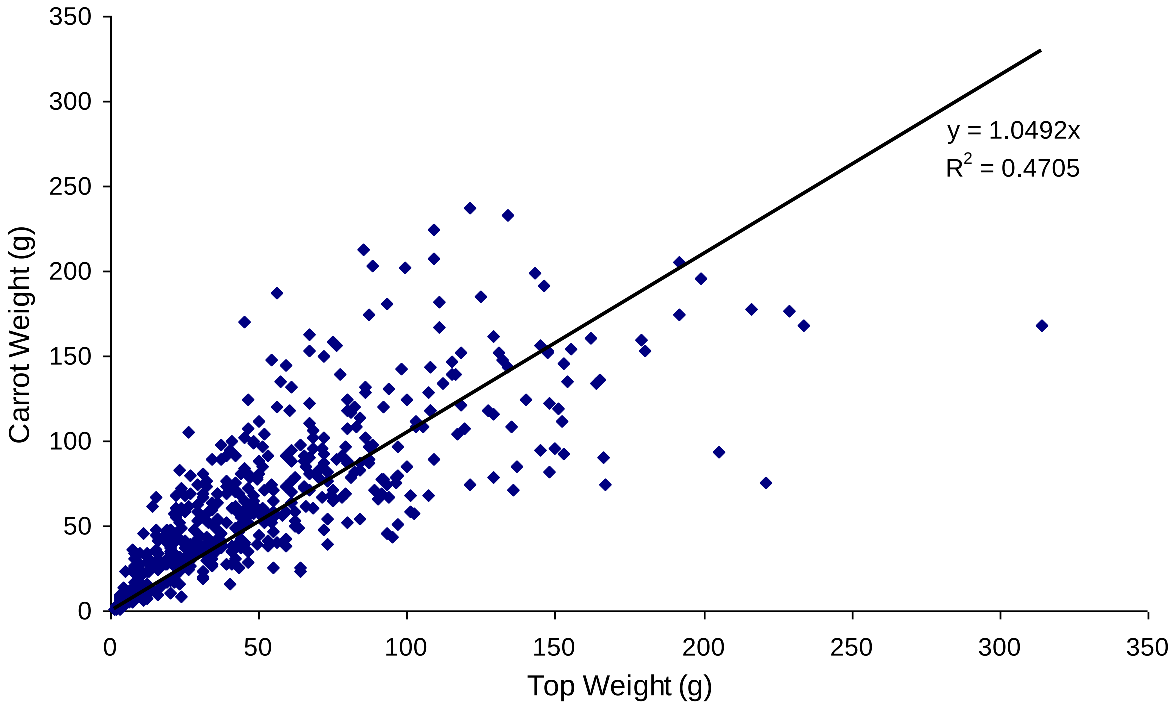


Figure 4.14. *BC0705: % Bolting 71-74 Days After Planting, classified by Plant Spacing (mm)*

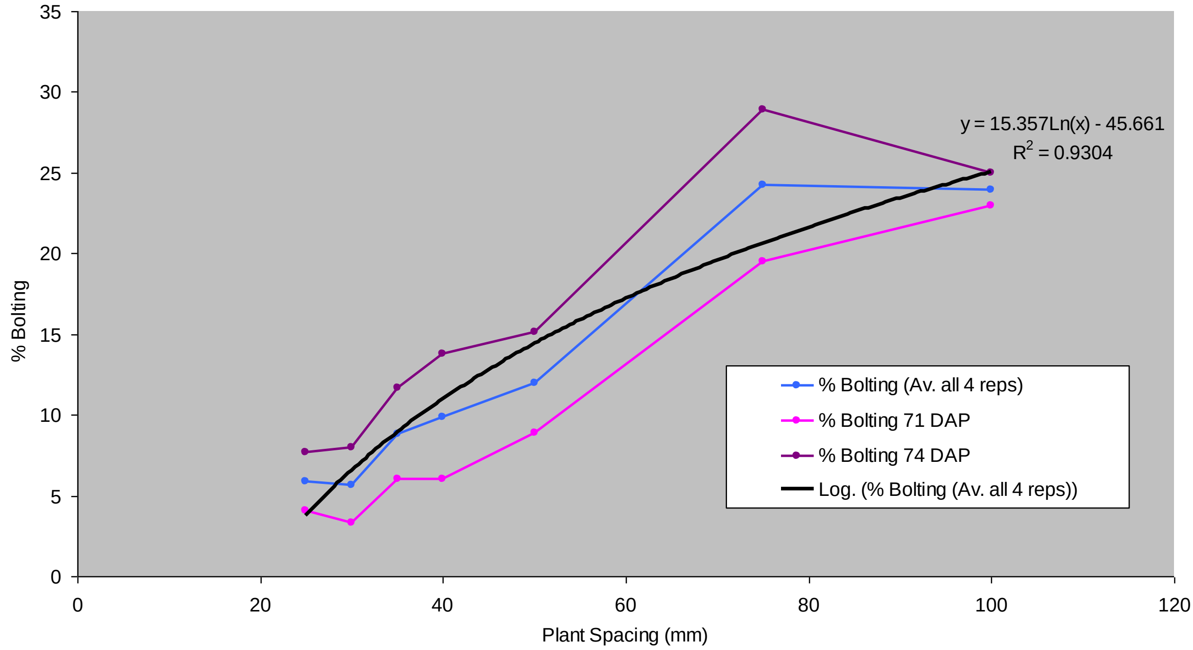
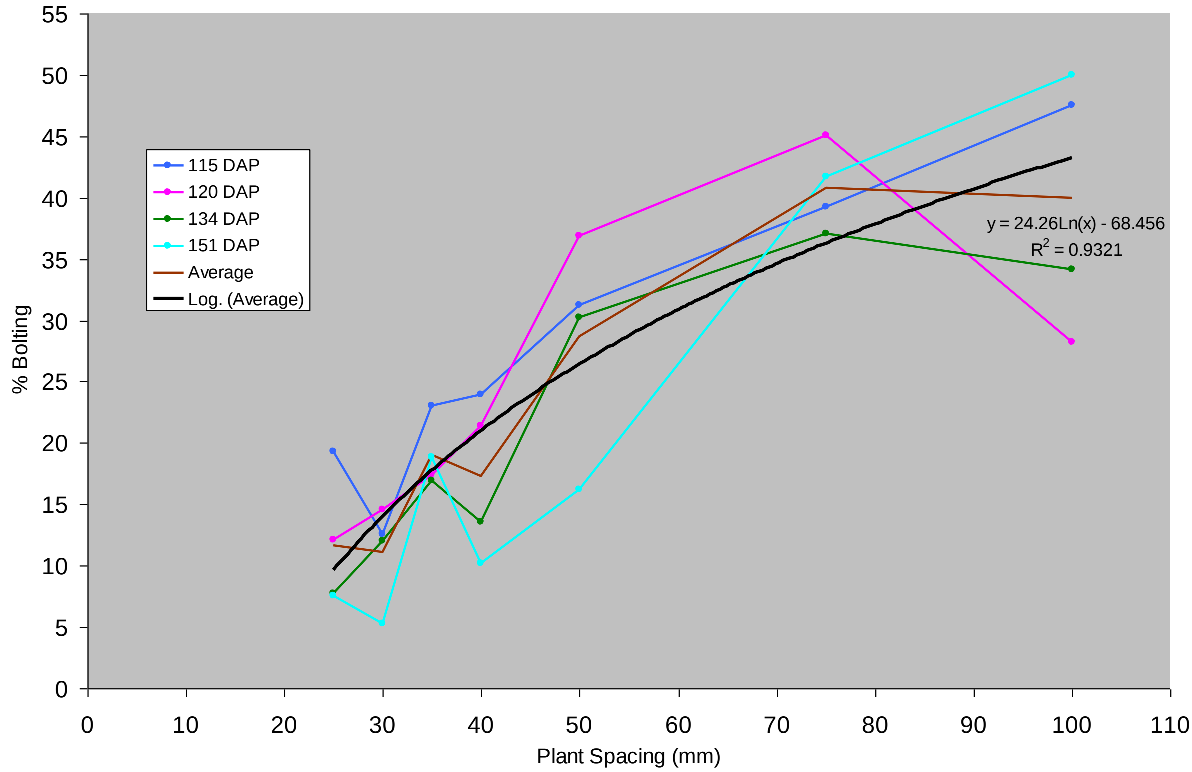


Figure 4.15. *BC0705: % Bolting at Harvest, classified by Plant Spacing (mm)*



Discussion (BC0705 – Clyde, Vic, 2007-08)

While the primary objective of the trial was to identify a plant spacing that showed the best combination of desirable harvest quality attributes, a range of other measurements were obtained for use in other sections of this report. As it was not possible to make detailed measurements for all plots on a single date, the four replications were harvested on different dates covering the range of harvest intervals used in commercial black carrot crops grown previously in Southern Australia.

As a result this trial also provided data for Section 3.2 of this report.

Bolting (Table 4.6 & Figures 4.14 & 4.15)

There was a very strong correlation between plant spacing and bolting. This phenomenon has been reported before (Dowker and Jackson, 1975). Lower density plantings bolted more severely. **Table 4.6 & Figures 4.14 & 4.15** show this very clearly. The trends seen at 71-74 DAP were practically identical at harvest. The level of bolting appeared to plateau at about 75 mm spacings, with both 75 & 100 mm spacings showing 40-41% bolting, significantly more than all closer spaced treatments. While differences were not always significant, the trend was numerically consistent and continued down to the two closest plant spacings (25-30 mm) which also appeared to show a lower limit plateau around 11-12%. In **Figure 4.14**, at 71-74 DAP, the log of the bolting average from all 4 replications was extremely well correlated (R^2 = 0.93). Similarly in **Figure 4.15**, at Harvest, the log of the bolting average from all 4 replications (4 different harvest dates) was again extremely well correlated (R^2 = 0.93).

Bolting significantly complicated yield data, but it also expanded the data obtained. With no previous indications of ideal planting times to avoid bolting, this trial was planted at a time that normally yields excellent carrot crops in the area. It was first observed 08 Jan 2008 (71-74 DAP) but had not been clearly evident on 18 Dec 2007 (50-53 DAP).

As **Figure 4.14** shows, the difference in bolting between different planting dates was quite striking, with replicates 1 & 2 (sown just 3 days later) showing markedly less bolting than replicates 3 & 4 (sown 3 only days earlier). LX3632 bolted much less severely in the adjacent variety trial (BC0706) sown just 9-12 days later than replicates 1 & 2 of the density trial, indicating a steep decline in bolting sensitivity over this period. In all cases bolting was far too high to be commercially acceptable. Further analysis of this issue is dealt with in Section 3.2.

As bolting occurred at a relatively high frequency that was also related to density, raw yield data was collected by counting and discarding bolting plants. Data was expressed in both raw and "bolting adjusted" forms. Bolting adjusted data attempted to remove the effects of bolting from results and was achieved by increasing the raw plot yield parameter by the proportion of plants that had bolted in that same plot.

Despite this extremely strong linkage between density and bolting, no clear mechanism has been identified. The author contends it might be related to how exposed the apical meristem is to cold (potentially higher density plantings provide greater insulation); how exposed the apical meristem is to sunlight, or a phytochemical effect based on the proximity of adjacent plants.

Yield Components

Carrots with a crown width less than 21 mm and less than 26 mm were separated, weighed and counted. The same was done for all larger carrots with no upper size limit. This allowed harvestable yields to be calculated using a minimum shoulder width specification of 21 or 26 mm.

Raw Carrot Yields (Table 4.2)

Raw plot yields consisted of all non-bolting carrots from largest to smallest harvested in each plot.

Total carrot yields were strongly linked to plant spacing. Yields in the 25-40 mm spacing group were highest and not significantly different, although the trend of increasing yield at closer spacings was strong. In particular, the two closest spacings of 25-30 mm were very close and still at more than 4.0t/ha higher than plants grown at 35 mm spacings. Yields at 75-100mm spacings were significantly worse than all other spacings.

Closer plantings also resulted in higher weights of undersized carrots, although there was some variation but little difference in the 25-35mm range. The trend was very consistent as a greater minimum size restriction was applied, particularly once the minimum size was 26 mm. At this point, spacings less than 40 mm showed high losses to undersize yield.

Bolting Adjusted Carrot Yields (Table 4.3 & Figure 4.2)

By adjusting for bolting the wider spacing treatments were less disadvantaged than as raw yield data before adjustment. Even after adjusting for losses from bolting, **Table 4.3** still showed similar trends. This was more visually demonstrated in **Figure 4.2**. Total yield still improved as plant spacing decreased, but the effect that removing undersize yield had on determining the ideal plant spacing made some of the intermediate spacings, particularly 40-50mm look much better.

If all carrots could be harvested, the 30mm spacing gave the highest yield. However, the 25-35mm spacing treatments had a much higher proportion of yield in the sub 26mm class than the wider spacing treatments.

The 40-50mm spacings were the most impressive treatments once yield below 26 or 21 mm was discarded.

Average Carrot Weights (Table 4.4 & Figure 4.3)

Figure 4.3 shows that average carrot weight was extremely well correlated with plant spacing (R^2 = 0.98). This was also born out through LSD analysis of the same results (**Table 4.4**). Wider plant spacings resulted in higher average carrot weights. Based on the strength of the correlation, the upper limit for average carrot weight is likely to plateau somewhere around 160 g.

Balancing yield with higher average harvestable weight was the single most important outcome of the trial. If a 26mm minimum width is imposed, the 50mm spacing showed markedly higher average weight carrots (111g) than closer spacings for virtually no significant yield penalty.

It becomes slightly more difficult using a 21mm minimum size as the 25-35 mm yield lifts significantly, but again, the average size is still significantly better at 50mm (100g compared to 72-83g).

Average Carrot Crown Width (Table 4.4 & Figure 4.4)

In line with other carrot size measurements, average carrot crown width closely mirrored average carrot weight trends.

Table 4.4 is particularly interesting as it shows clearly at what point average crown width was equivalent to plant spacing. Theoretically at this point, carrots are growing shoulder to shoulder, though in reality, the variability in LX3632 meant this was not actually seen. It was observed though in the processing standard variety Red Hot in an adjacent trial. At 25 mm, individuals in the originally planted population seemed to have been removed by competition, giving a crown width just slightly greater than the plant spacing. At 30 mm plant spacing, the average carrot crown width was also 29.6 mm. At 35 mm plant spacings, the average crown diameter was 30.4 mm, indicating around 4.6 mm of space between adjacent carrots (on average). This carrot free row space then simply continued to increase as plant spacings increased.

Figure 4.4 shows that average crown width was extremely well correlated with plant spacing (R^2 = 0.9817). This was also born out through LSD analysis of the same results (**Table 4.4**). Wider plant spacings resulted in higher average crown widths. Based on the strength of the correlation, the upper limit for average carrot weight is likely to plateau somewhere around 42-43 mm.

Canopy Weights & Canopy/Carrot Weight Ratios (Tables 4.5, 4.6 & Figures 4.5–4.13)

The most important finding here was that large tops tended to be associated with large carrots and furthermore the ratio of top/carrot weights did not vary sufficiently to make density a useful tool for canopy weight manipulation.

While all carrots in all plots were weighed and crown widths measured for each individual, only in replicate 3 was the same done for top weights. This was purely a time related consideration.

Looking at individual plant top and carrot weights (replicate 3 = 115 DAP in **Figures 4.6-4.12**), the first point to note is the relatively poor correlations seen for each plant spacing. In other words, within any population sampled, the top/carrot ratio varied considerably (R^2 = -0.2239 – 0.6889). Even when all the results from all spacings were pooled (**Figure 4.13**), the correlation was still poor (R^2 = 0.4705). This meant that while the exact relationship between top and carrot weights varied considerably for individuals, population average figures measured across different groups were significant.

Table 4.5 shows that broadly, canopy weights decreased as plant spacings increased. This was true whether or not the data was adjusted for bolting, although the statistical separation was better for raw data. Average top weights which also ignored bolting material (total top weight in a plot divided by the number of carrots harvested) was also well statistically separated and showed higher average top weights as plant spacing increased. This data has been plotted in **Figure 4.5**, although correlations using top/carrot weight ratios were poor whether based on average unit plant weights (R^2 = 0.48) or total yields (R^2 = 0.25). Canopies were typically about 60-65% of carrot weights from the same area sampled.

Brix, Absorbance & Anthocyanin Content (Table 4.7)

Higher Brix showed a weak association with wider plant spacings, but the trend was inconsistent and no differences were significant.

Any statistical differences in the anthocyanin results are aberrations as the only two significantly different spacings were adjacent (35 and 40 mm) and not the extremes. The variance between and within samples was extremely high, even for the similar treatments.

Carrot Forking, Cracking & Production of Enlarged Fibrous Roots (Table 4.8)

Damage to the tap root giving rise to forking and "stumping", side shoot development and fibrous roots are normally associated with disease, nematodes or physical damage, particularly during early development. Deformities of these types were commonly problematic on the farm where this trial was conducted. Recent attempts by the grower to identify the likely causes indicated that nematodes were not present and that *Pythium* was the most likely cause. A detailed record was made for individual carrots from each plot sample in case important trends emerged. Full details recording for example how far down the carrot "blunting" occurred, how many side-shoots, how many fibrous roots, how many and how severe cracking were all recorded. However, no treatment related trends were observed.

The only statistically analysed data was the total incidence of forking (including stumping and side shoot development), incidence of cracking (all sizes) and the incidence of enlarged fibrous roots. While it appears as if these enlarged fibrous roots may simply be a lesser manifestation of more major forking, the specific cause might be identified in future work focused on disease control.

Cracking is a significant problem in conventional B-carotene carrots like Red Hot, not just black carrots. This seems mainly to be associated with variability in moisture availability but other factors such as variety and excessive use of Nitrogen also appear to have an effect (Hartz *et al*, 2005). There were no treatment related effects on cracking.

The only deformity that was related to plant spacing was forking and this was seen to be an indirect relationship. Larger carrots showed more forking and since wider spacings produced larger average sized carrots, the wider spaced carrot treatments also had a higher proportion of forked carrots. The effect though was not significant below 50 mm spacings.

Cracking was highly varied but not in any way related to plant spacing.

Materials & Methods (BC0808 – Parilla, SA, 2009)
This was a supplementary trial only initiated after the results from the main density study (BC0705) suggested black carrots might "self thin", allowing the strongest plants to dominate the population.

This trial was conducted alongside several other smaller studies and as such the treatments were not purely density related. As seed is often provided in different forms, it is not always possible to use identically treated seed. Originally the trial was designed to simply compare a plot of unthinned plants with one thinned to approximately 30 mm spacings.

However, a number of interesting results from several plots nearby were included as they seem to have been very closely related to plant density and many of the results seen in the main study BC0705. The author believes these small differences in seed or soil treatment would have had little impact on the harvest parameters measured. Firstly, the seed and soil treatments did not seem to give any clear additional control to regular seed at this site (Section 9.1). Secondly, these types of treatments are intended to improve plant establishment and early vigour not the harvest parameters this trial measured. There were no clear trends to suggest these additional treatments had affected harvest parameters.

N-Crust is simply a clay based coating used to assist pickup in vaccum seeders and breaks down as soon as it comes into contact with moisture. It contains no chemicals or nutrients. Pro-Pellet-M is a proprietary nutrient coating to provide seed with a readily available supply of nutrients during germination.

With the exception of the Apache which was not thinned, plants were thinned by eye at about 2-3 weeks of age. The plant spacings indicated were not chosen but measured precisely after plots were harvested by dividing the total length harvested (1.0 m of bed = 6.0 linear m of row) by the number of carrots recovered.

Location

This trial was located at the Parilla Premium Potatoes, Parilla, SA (approx: 35° 17′ 42″ S, 140° 42′ 38″ E), on a carrot/onion/potato rotational, yellow sand, typical of the region.

Design

Plots were unreplicated, consisting of three pair-planted rows (6 single rows in total) on a single bed 1.6 m wide (bed centre to adjacent bed centre), 2.0 metres long. Beds were formed. LX3632 and Apache (grower standard variety) were used.

Table 4.9. *BC0808: Treatment (plant density) Details*

Treatment	Plant Spacing (mm)	Variety	Plants /m of bed	Additional Treatment Factors
1	**8**	LX3632	750	NCrust seed coating + Azoxystrobin soil drench at planting
2	**13**	LX3632	462	Pro-Pellet-M seed coating + Azoxystrobin soil drench at planting
3	**24**	LX3632	250	Azoxystrobin soil drench at planting
4	**41**	LX3632	146	Higher Rate azoxystrobin soil drench at planting
5	**67**	Apache	90	Nil

Irrigation

Centre-pivot applied from 1-3 times every 24 hours outputting 4-12 mm every 24 hours during the Dec-Feb period and then daily to weekly applications during the coolest periods.

Nutrition

Grower applied as for the surrounding commercial crop. This included a balanced NPK fertilizer providing approx 100 kg/ha N. Foliar applications of N as urea and trace elements were made every 10-14 days through the centre-pivot irrigator

Other

All seed (apart from the grower standard – Apache) was hand planted on 01 Jan 2009, to a depth of about 5-10 mm by marking lines for rows, creating a shallow furrow with a vee-shaped aluminium tyne, then sprinkling seed along furrows in excess of requirement and lightly covering furrows by hand.

Seedlings were thinned a fortnight later to approximately 25-40 mm. The Apache was not hand thinned.

Linuron 500 gai (active ingredient)/kg + prometryn 500 gai/L applied at 0.5 Kg/ha + 0.25 L/ha respectively were applied at approximately 8 weeks after planting to control a range of weeds, particularly caltrop.

Evaluations

Photographs were taken at various stages of crop development. Where bolting occurred it was measured soon after it occurred and again just prior to harvest. 1.0 m whole bed (6 row) samples were harvested by hand 06 Jul 2009 with a pitch fork from the centre-section of the 2.0 m plots. All plant material was collected. Tops were removed by hand. Carrots were individually sorted into size categories (26+, 21-25 mm & <21 mm) according to the widest point at the shoulders (crown). Branched or otherwise deformed carrots were separated within each of these size groupings from unforked carrots. Each of these categories were weighed and individual carrots in each group counted.

Results (BC0808 – Parilla, SA, 2009)

Figure 4.16. *BC0808: Total & Component Yields (tonnes/ha), classified by Plant Spacing (mm) for Black (LX3632) and Apache carrots.*

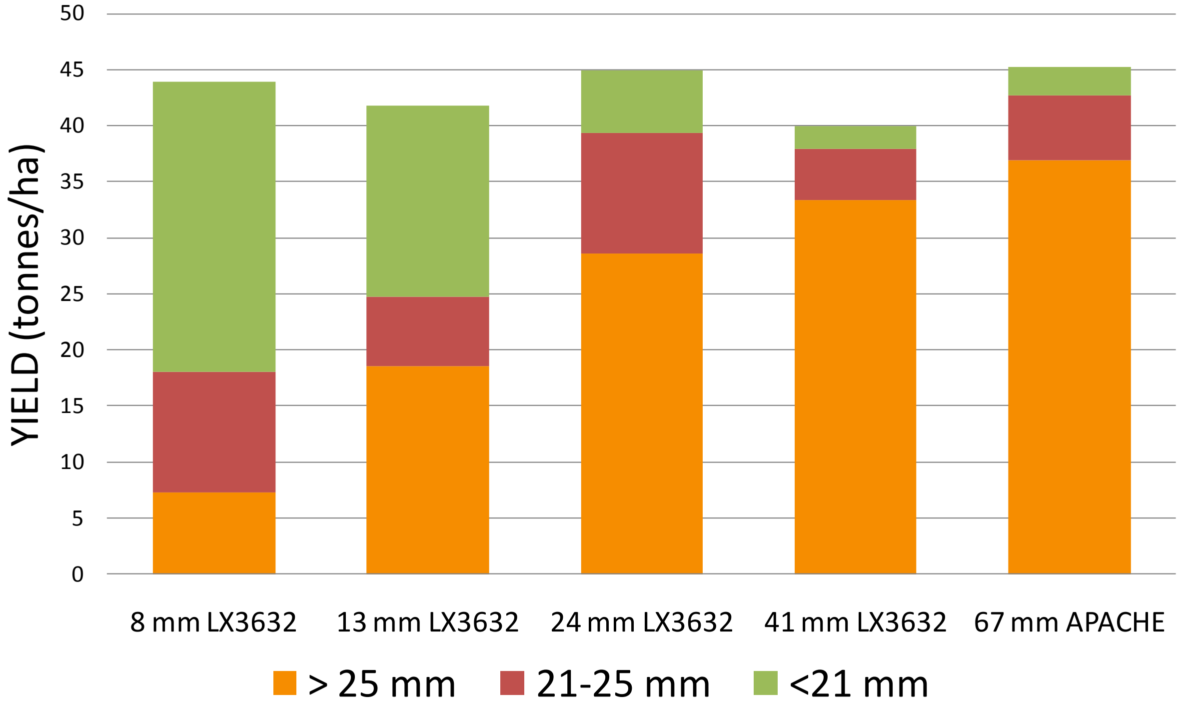


Figure 4.17. *BC0808: Average carrot weights (g) for all size classes, classified by Plant Spacing (mm) for Black (LX3632) and Apache carrots.*

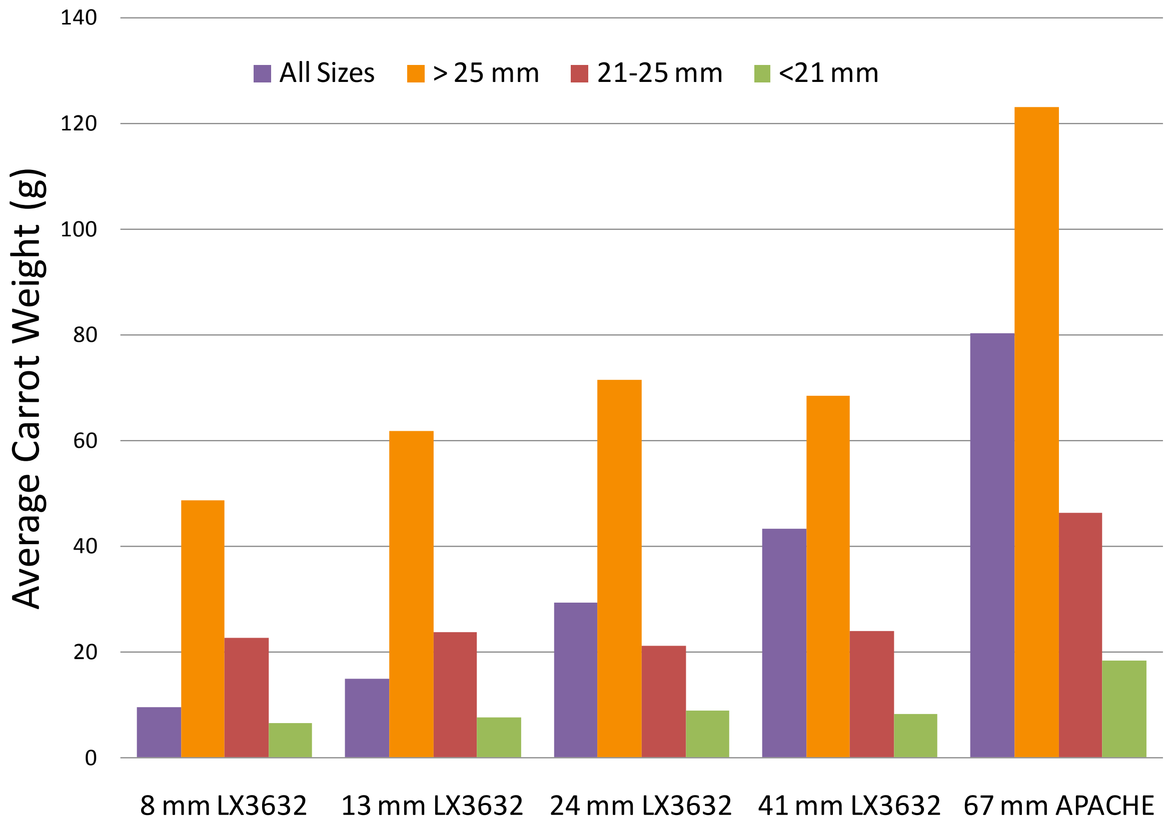


Figure 4.18. *BC0808: Plants/metre of bed, for all size classes, classified by Plant Spacing (mm) for Black (LX3632) and Apache carrots.*

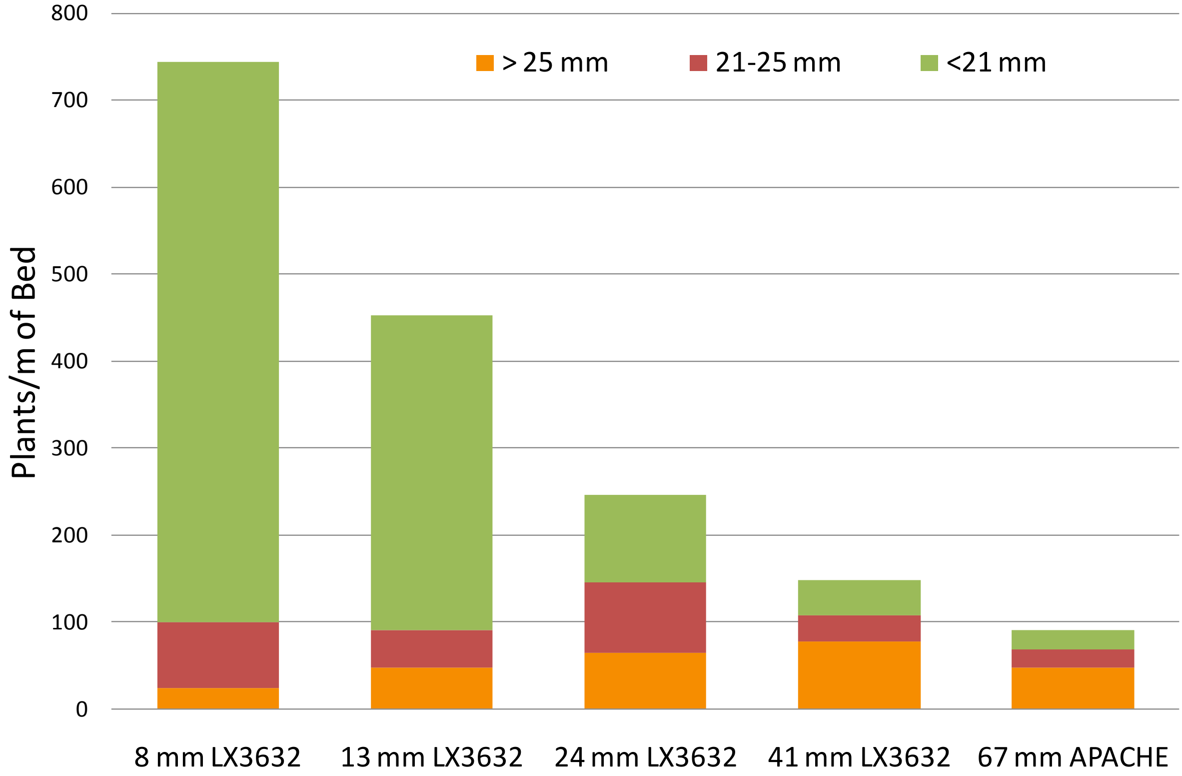


Figure 4.19. *BC0808: Plants/metre of bed, for all size classes, classified by Plant Spacing (mm) for Black (LX3632) and Apache carrots.*

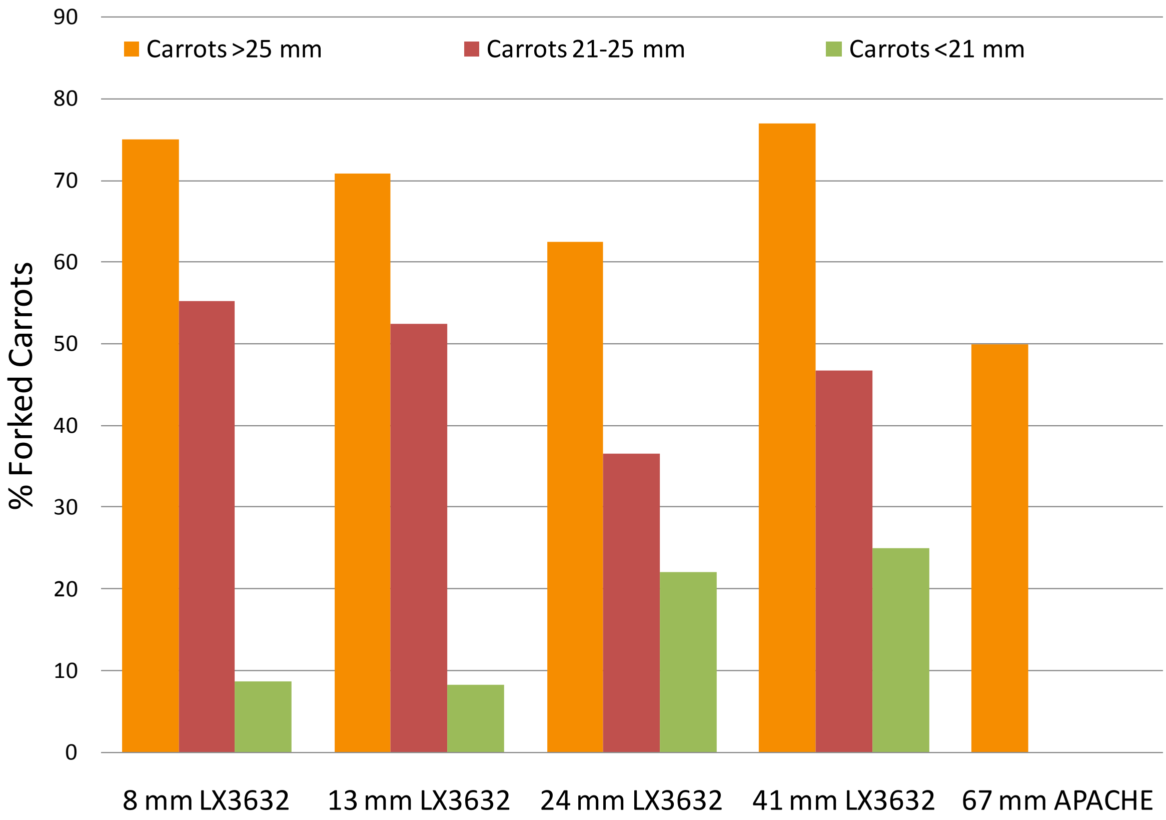


Table 4.10. *BC0808: Anthocyanin Content for Black (LX3632) carrots, classified by Plant Spacing (mm).*

Plant Spacing (mm)	Additional Treatment Factor	Absorbance at 538 nm	Anthocyanin Content (mg% at 8.0° Brix).
8	Az at Planting (High Density + NCrust)	0.752	77
13	Az at Planting (High Density + Pro-Pellet-M)	0.829	85
24	Az at Planting	0.834	86
31	Untreated	0.704	72
35	High Az + Met-m at Planting	0.592	61
38	Az Early Post-em	0.732	75
41	High Az at Planting	0.977	100
43	Met-m at Planting	0.752	77

Table 4.11. *BC0808: % °Brix and pH, classified by Plant Spacing (mm) for Black (LX3632) and Apache carrots.*

Plant Spacing (mm)	Brix (°Br)	pH
LX 3632 8 mm	9.4	6.30
LX 3632 13 mm	11.6	6.31
LX 3632 24 mm	12.0	6.32
LX 3632 41 mm	11.4	6.33
Apache 67 mm	11.1	6.39

Discussion (BC0808 – Parilla, SA, 2009)

As seen in many other trials on this property, LX3632 failed to produce large carrots compared with other locations. It is believed this is most likely related to the extra water required by LX3632 especially during early establishment which was not available as watering was applied to the lesser requirements of Apache.

In addition, this particular part of the paddock seemed to have a duplex soil which caused an unusually large number of carrots to fork.

Trial results should be used as a guide to support trends seen elsewhere as the plots were not replicated.

Bolting

No bolting occurred in any treatment in this trial.

Total and Component Carrot Yields (Figure 4.16)

Total yields were remarkably similar not only across the 8-41 mm spacings for LX3632 but also across the two varieties. All plots returned a total yield between 40 and 45 tonnes/ha (only 11% variance from highest to lowest yields).

Component yields varied enormously. There was a clear trend towards higher proportions of the total yield coming from smaller grade carrots as plant spacing decreased. At 8 mm spacings, the smallest grade carrots accounted for more than half the total weight, while at 13 mm, the smallest grade carrots accounted for just under half the total weight harvested. At 24 mm spacings the smallest grade carrots were only around 15% of the total harvested weight and at 41 mm about 5%. Apache at 67 mm and LX3632 at 41 mm showed similar proportions of component class yields.

Average Carrot Weights (Figure 4.17)

In accord with the increasing yields of larger carrots as plant spacing increased, so too did average carrot weights (all sizes and >25 mm classes) increase as plant spacing increased.

Average carrot weights for the undersized categories (21-25 and <21 mm) were similar across all LX3632 treatments as expected. However, Apache showed far greater development in all size categories including the undersized ones. Even at a more widely spaced than desirable interval of 67 mm, Apache managed to effectively use the extra space to create additional yield by growing larger harvestable size carrots, whereas LX3632 appeared to have no ability to produce larger carrots above 24 mm spacings.

Plants/m of Bed in all size categories (Figure 4.18)

The most compelling aspect of this figure is the steady increase in the proportions and numbers of more desirable, larger carrots all the way up to 41 mm. This lends weight to the findings of BC0705 that undersized yield will continue to account for an unacceptably large number of plants until a spacing of 41 mm or more is attained.

% Carrot Forking (Figure 4.19)

Levels of forking were extremely high even compared with other situations LX3632 has been grown and forked significantly. This was thought to be related either to the duplex sand over clay soil or inadequate early moisture or both of these.

There were no clear indications that forking was related to carrot densities. Within any treatment, the trends were same with a greater level of forking in progressively larger carrots.

Apache showed markedly less forking in the >25 mm category and no forking at all in the smaller grades.

Anthocyanin Content (Table 4.10)

Anthocyanin levels were extremely variable both within and between individual samples. In an attempt to establish a more meaningful estimate, a number of other plots planted the same day for use in other trials have also been included. As with the other treatments, plant spacings were calculated in the same way. The additional treatment factors are outlined in the Table. These additional treatments were not included in the other data tables and figures in order to reduce soil treatment variables (metalaxyl-m or other timings of azoxystrobin application).

As in BC0705, there was no compelling evidence that plant spacings significantly affected anthocyanin content.

Brix and pH (Table 4.11)

Brix and pH were similar both across different densities of LX3632 and between the two varieties. The Brix figures in particular show LX3632 has the capacity to produce similar soluble solids to Apache under similar conditions. A Brix reading above 11.0 as seen in this trial is highly desirable.

Materials & Methods (BC0905 – Clyde, Vic, 2009)
This was a more rigorous supplementary trial than BC0808, initiated after the results from the main density study (BC0705) suggested black carrots might “self thin”, allowing the strongest plants to dominate the population.

Location:

This trial was located near Clyde (approx: 38° 09′ 05″ S, 145° 20′ 38″ E) inside a dedicated bay separate from commercial bunching vegetable crops (Dutch Carrots, Bok-Choy, Bunching onions etc), on very light sandy black soil, typical of the region.

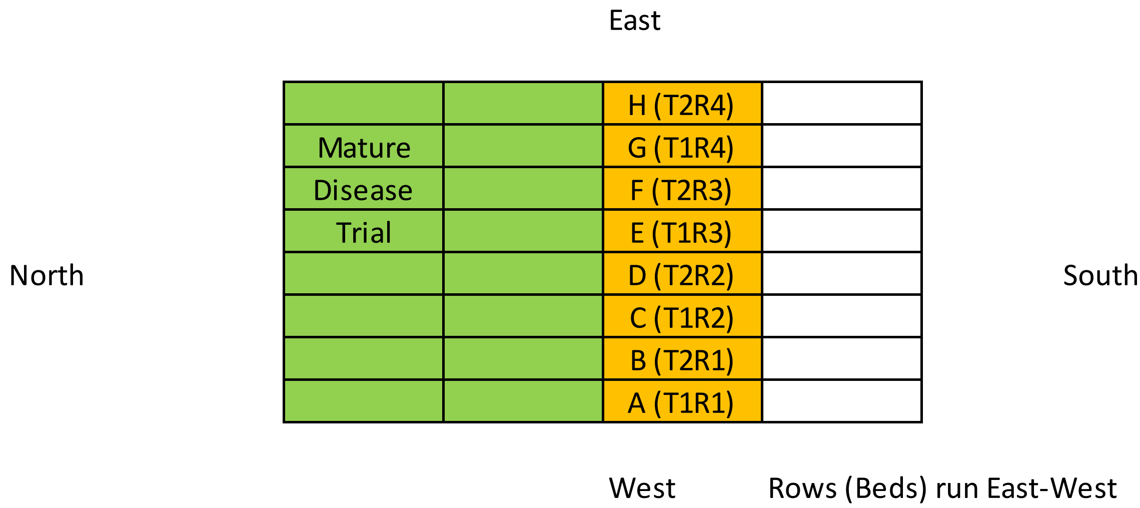
Design

Plots were replicated four times, consisting of two pair-planted rows (4 single rows in total) on a single bed 1.6 m wide (bed centre to adjacent bed centre), 2.0 metres long. Beds were formed. LX3632 and Apache (grower standard variety) were used.

Table 4.9. *BC0905: Treatment (plant density) Details*

Treatment	**Description**	**Av. Plant Spacing (mm)**	**Variety**	**Plants/m of bed**
1	Unthinned	**18.4**	LX3632	217
2	Hand thinned 10-14 days after sowing	**36.3**	LX3632	110

Figure 4.20. *BC0905 - Trial Layout.*



Irrigation

Irrigation was provided by solid set sprinklers arranged in a square grid pattern with 10 metres between risers. Irrigation intervals were determined by the grower and scheduled as for the rest of the farm, typically a single application of 6 mm/day at the beginning to a 8-10 mm/day during the hottest parts of summer.

Nutrition

Pre-trial nutrition report indicated adequate major and trace elements were available. Hortico Aquasol™ applied at 2.0 g/m^2 28 May 2009. Soil test sampled 16 Jun 2009 showed trace and minor element deficiencies (Ca, Mg, Bo, Cu, Fe, Mg & Mo). Gypsum applied at 1.0 kg/m^2 + Hortico Aquasol™ also applied at 2.0 g/m^2 on 25 Jun 2009.

Other

All seed was hand planted on 12 Feb 2009, to a depth of about 5-10 mm by marking lines for rows, creating a shallow furrow with a vee-shaped aluminium tine, then sprinkling seed along furrows in excess of requirement and lightly covering furrows by hand.

Seedlings in Treatment 2 were thinned 24 Feb 2009 to approximately 35 mm.

Linuron 500 gai/kg applied at 0.5 Kg/ha post-sowing, pre-emergence (same day as planting) and incorporated with 8 mm of irrigation.

Evaluations

Photographs were taken at various stages of crop development. Where bolting occurred it was measured soon after it occurred and again just prior to harvest. 1.0 m whole bed (4 row) samples were harvested by hand 06 Aug 2009 with a pitch fork from the centre-section of the 2.0 m plots. All plant material was collected. Tops were removed by hand. Carrots were individually sorted into size categories (26+, 21-25 mm & <21 mm) according to the widest point at the shoulders (crown). Branched or otherwise deformed carrots were separated within each of these size groupings from unforked carrots. Each of these categories were weighed and individual carrots in each group counted.

Results (BC0905 – Clyde, Vic, 2009)

Table 4.10. *BC0905: Yields – All Sizes (t/ha), classified by Plant Spacing (mm)*

Plant Spacing (mm)	TOTAL Yield - Carrots (t/ha)	Plant Spacing (mm)	YIELD 21+ mm - Carrots (t/ha)	Plant Spacing (mm)	YIELD 26+ mm - Carrots (t/ha)
36	34.605 I	**36**	33.359 I	**36**	30.298 I
18	33.678 I	**18**	28.548 I	**18**	21.620 I
Transformation	None	Transformation	None	Transformation	None

Table 4.11. *BC0905: Harvestable Yields as a % of Total Yield by **Weight**, classified by Plant Spacing (mm)*

Plant Spacing (mm)	YIELD Proportion 21+ mm - Carrots (%)	Plant Spacing (mm)	YIELD Proportion 26+ mm - Carrots (%)
36	96.4 I	**36**	87.5 I
18	84.6 I	**18**	63.9 I
Transformation	Arcsine Sqrt	Transformation	None

Figure 4.21. *BC0905 – Component Yields (t/ha) based on carrot shoulder width (mm), classified by Plant Spacing*

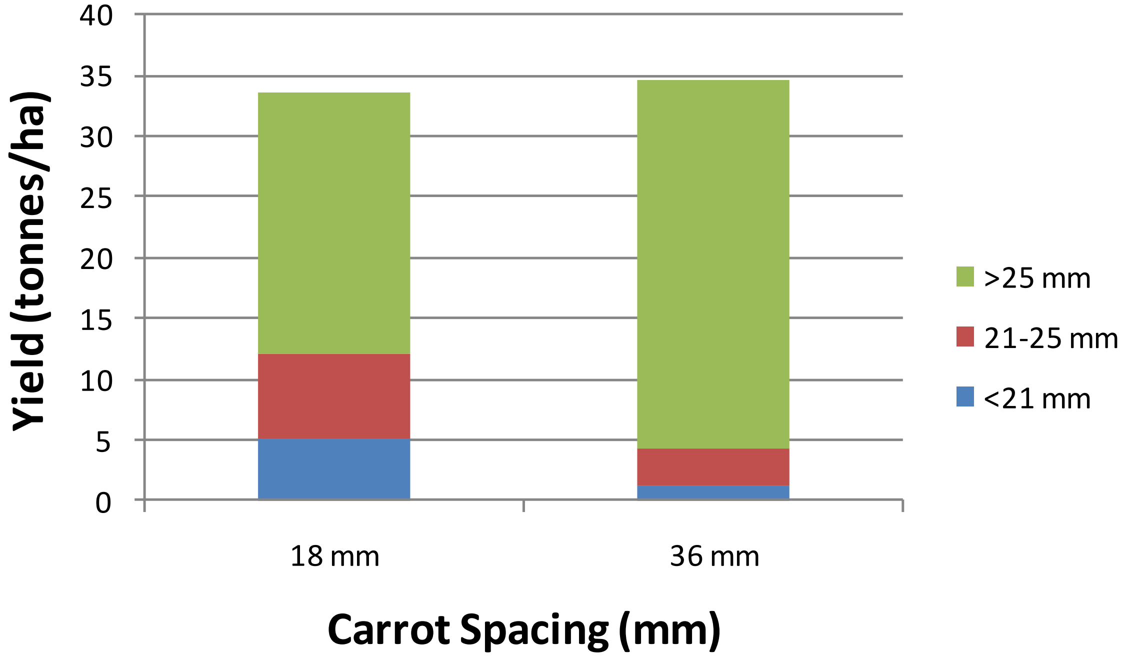


Table 4.12. *BC0905: Total No. of Carrots/ha for all sizes, classified by Plant Spacing (mm)*

Plant Spacing (mm)	Carrots/ha (All Sizes)	Plant Spacing (mm)	Carrots/ha (21+ mm)	Plant Spacing (mm)	Carrots/ha (26+ mm)
36	690,625 I	**36**	543,750 I	**18**	343,750 I
18	1,373,438 I	**18**	634,375 I	**36**	423,438 I
Transformation	None	Transformation		Transformation	None

Table 4.13. *BC0905: % Harvestable Yield by* ***Numbers****, classified by Plant Spacing (mm)*

Plant Spacing (mm)	YIELD Proportion 21+ mm - Carrots (%)	Plant Spacing (mm)	YIELD Proportion 26+ mm - Carrots (%)
36	78.8 I	**36**	61.3 I
18	46.7 I	**18**	25.3 I
Transformation	None	Transformation	None

Table 4.14. *BC0905: Av. Carrot Weights (g) for all sizes, classified by Plant Spacing (mm)*

Plant Spacing (mm)	Average Carrot Weight (g) All Sizes	Plant Spacing (mm)	Average Carrot Weight (g) 21+ mm Sizes	Plant Spacing (mm)	Average Carrot Weight (g) 26+ mm Sizes
36	50.3 I	**36**	61.4 I	**36**	71.8 I
18	24.8 I	**18**	45.0 I	**18**	62.8 I
Transformation	None	Transformation	None	Transformation	None

Table 4.15. *BC0905: % Forking by Weight and Number, classified by Plant Spacing (mm)*

Plant Spacing (mm)	% Forked Carrots by Weight	Plant Spacing (mm)	% Forked Carrots by Number
36	7.9 I	**36**	8.4 I
18	9.2 I	**18**	5.3 I
Transformation	None	Transformation	None

Table 4.16. *BC0905: Canopy Weights (t/ha) and weights as a proportion of total plant weight (%), classified by Plant Spacing (mm)*

Plant Spacing (mm)	Canopy Weight (t/ha)	Plant Spacing (mm)	Canopy Weight as a % of Total Plant Weight
36	21.622 I	**36**	38.2 I
18	21.475 I	**18**	38.8 I
Transformation	None	Transformation	None

Table 4.17. *BC0905: Actual Average Plant Spacing & Late Bolting Plants (%), classified by Plant Spacing (mm)*

Plant Spacing (mm)	**Actual Plant Spacing (mm)**	**Plant Spacing (mm)**	**% LATE Bolting (175 DAP)**
36	36.3 I	**18**	1.8 I
18	18.4 I	**36**	0.8 I
Transformation	None	Transformation	None

Table 4.18. *BC0905: Carrot Juice pH & Brix, classified by Plant Spacing (mm)*

Plant Spacing (mm)	**pH**	**Plant Spacing (mm)**	**Brix (°Br)**
36	6.2 –	**18**	11.1 I
18	6.1 –	**36**	10.8 I
Transformation	Failed	Transformation	None

Table 4.19. *BC0905: Carrot Juice Anthocyanin Absorbance (@538 nm) & Concentration (mg% at 8.0° Brix), classified by Plant Spacing (mm)*

Plant Spacing (mm)	**Absorbance (@538 nm)**	**Plant Spacing (mm)**	**Anthocyanin Content (mg% @ °Br)**
18	0.6968 I	**18**	71.6 I
36	0.6395 I	**36**	65.7 I
Transformation	None	Transformation	None

Discussion (BC0905 – Clyde, Vic, 2009)

Plant Numbers

Plants were not deliberately thinned to these exact spacings. The 18 mm treatment is simply the final establishment density in the unthinned treatment, whereas the 36 mm interval was the actual average spacing after hand thinning treatment 2.

Table 4.12 shows significantly higher numbers of plants in total/ha, as would be expected when one treatment was deliberately thinned and the other not. Similarly in the first column of Table 4.17, the actual plant spacing was found by dividing the length of single carrot row harvested in a plot (4.0 m) and dividing by the number of carrots recovered.

Bolting (Table 4.17)

No early bolting hindered good crop development. But by harvest (days after planting) plants had just begun to bolt, indicating optimum time for harvest was ending. The level of bolting was very low and the difference was not significant, nor did it impact on yield to any extent requiring adjustment.

Total and Component Carrot Yields (Tables 4.10, 4.11 & 4.13 & Figure 4.21)

Total yields were again remarkably similar. All plots returned a total yield around 33-35 tonnes/ha.

Figure 4.21 clearly shows component yields were strongly and significantly linked to plant spacing. Higher proportions of the total yield came from smaller grade carrots as plant spacing decreased. This trend was the same and differences were significant whether component yields were based on a % by weight (Table 4.11) or % by number basis (Table 4.13).

Average Carrot Weights (Table 4.14)

In accord with the increasing yields of larger carrots as plant spacing increased, so too did average carrot weights (all sizes, 21+ and 26+ mm classes) increase as plant spacing increased. The difference was significant in the case of the 21+ mm category and the all sizes category. The variance in the case of the 26+ mm category prevented the difference being significant but the trend was the same.

Canopy Weights (Table 4.16)

Total canopy weights were not significantly different and both measured around 21-22 tonnes of fresh weight/ha. For both density treatments this represented 38-39% of total plant weights harvested from plots, again not significantly different. This again shows that plant density is not an effective tool for canopy manipulation.

% Carrot Forking (Figure 4.15)

Levels of forking were low compared with other situations LX3632 has been grown. As with the other density studies, there were no indications that forking was related to carrot densities. This was true whether assessed by weight (8-9%) or number of carrots (5-8%).

Anthocyanin Content (Table 4.19)

There were no significant differences between the two density treatments with both falling inside a 66-72 mg% (@8.0° Br) range.

Brix and pH (Table 4.18)

Brix was good at near 11.0 for both densities but not significantly different. Acidity (pH) was inside the standard range (6.1-6.2) and not significantly different with both densities.

References

Hartz TK, Johnstone PR, Nunez JJ (1966). Production environment and nitrogen fertility affect carrot cracking. HortScience, Vol. **40**, No. 3, pp. 611-615.

5 Identifying Key Nutritional Requirements & Manipulating Black Carrot Canopy Volume

Introduction

One of the most distinctive features of black carrots is the much larger canopy size and rate of development compared with conventional high carotene carrots. This is evident from early post germination until full canopy development. Very often these large tops do not seem to produce particularly large carrots underneath, in comparison to Red Hot or Apache for example. One of the earliest ideas in developing project objectives was whether the apparently excessive use of plant energy and resources might be diverted from top growth to roots.

Two key methods were proposed for closer examination of this idea – manipulating nutrition, particularly nitrogen and to a lesser extent, the use of plant growth regulators. Manipulating crop nutrition is examined in this Section (5), while the use of plant growth regulators is investigated in Section 6.

Of the less likely avenues for manipulating canopy development, the effects of plant density on canopy vigour are examined in Section 4, and the effects of manipulating irrigation, in Section 10.

Key Outcomes

For Excel Fresh variety LX3632:

- Manipulating crop available nitrogen was neither reliable nor effective for altering the partitioning of crop photosynthates away from shoot into root development.

- Black carrots were very insensitive to surplus nitrogen and showed no clear tendency to use it for extra shoot or root growth. This is consistent with previous studies in more conventional orange carrots.

- High black carrot yields require large canopies.

- Black carrots appeared to be very effective nutrient "scavengers", particularly of N & P, capable of growing well even when soil nutrient levels (referenced for standard carrots) indicate marginal availability or even deficiencies.

- Black carrot yield and quality was very poorly correlated to nutrition levels applied. There appeared to be a number of other more important soil factors such as drainage and moisture availability that influenced yield more than nutrition in the normal range (extreme deficiencies and excesses did not occur).

- Reference (Guide) foliar nutrient levels for black carrots are likely to be somewhat lower than for ordinary orange carrots. Foliar nutrient levels in black carrots are very dependent on the vigour of material sampled. Larger, greener canopies showed greater nutrient dilution than smaller, often yellower material. Leaf nutrient levels in black carrots leaves were often found to be lower than in Red Hot carrots grown in the same trial, because of the same growth dilution seen in the larger canopies of black carrots.

- Back carrot nutrition should generally follow standard carrot recommendations for the areas they are being grown in. LX3632 & Red Hot typically use similar amounts of nutrients/ha when grown under similar conditions. The canopy represents about 28-42% of total crop weight in black carrots (LX3632) but only about 16-22% of the total crop weight in Red Hot. As most nutrients are found in higher concentrations in the leaves than in the carrots, LX3632 takes up considerably more of most nutrients than Red Hot per tonne of total plant weight and even more per tonne of carrot yield. Total yields of LX3632 are typically only about 60% of Red Hot under similar conditions.

- Black carrots require a steady supply of N, P, K, Cu, Mn & Zn for the duration of the cropping cycle with no specific periods of peak demand. Adequate P& K for the whole cropping cycle should be made available in a base fertilizer at planting. N is best supplied steadily throughout the season to avoid leaching and denitrification losses. Cu, Mn & Zn need to be monitored and applied any time foliar levels become marginal.

- From the main trial:

    The key period for S & B demand is 0-6 weeks after planting. These nutrients should be sufficiently available in the soil or supplemented in base fertilizer at planting.

    The key period for Ca, Mg & Mo demand is 6-10 weeks after planting.

    The key period for Fe demand is 10-21 weeks after planting.

- From harvested tissue (carrots and tops) calculations, a 35-50 t/ha crop of black carrots uses approximately 240-402kg K/ha, 69-193kg N/ha, 100-136kg Cl/ha, 39-65kg Ca/ha, 21-36kg P/ha, 13-16kg S/ha, 11-13.5kg Mg/ha, 373-761g Fe/ha, 183-310g B/ha, 160-346g Zn/ha, 149-225g Mn/ha, 22-46g Cu/ha & 1.8-7.4g Mo/ha.

- Many of the most suitable production regions are on sandy soils which also tend to be very deficient in a range of minor and trace elements. Particular attention needs to be paid to addressing known trace element deficiencies. Trace element deficiencies were more likely to be the cause of poor yields in these studies than major element deficiencies which were nearly always found at adequate to high levels in these studies.

Materials & Methods (BC0801 – Dareton, NSW, 2008)

This was the main trial used to obtain ideal plant spacing recommendations.

Location
This trial was located at the NSW DPI Research Station near Dareton, NSW (approx: 34° 05′ 43″ S, 142° 00′ 53″ E, elevation 51 m) inside a dedicated area worked up managed solely for the purpose of conducting the trial, on a red loamy sand, typical of the region.

Design
Plots (Varieties) were replicated four times in randomised complete blocks. Plots consisted of two pair-planted rows (4 single rows in total on a 10/40/10) on a single bed 1.6 m wide (bed centre to adjacent bed centre), 3.2 metres long.

Base Nutrition
As this was primarily a nitrogen study, care was taken to avoid applying ANY nitrogen as a base. All nitrogen was applied as urea (see treatment list in Table 5.1 below).

14 Jan 2008: Hifert Single Superphosphate (0:9:0 N:P:K) applied at 500kg/ha (45kg P/ha) and incorporated to 60cm with deep ripper. 15 Jan 2008: Hifert Sulfate of Potash (0:0:41:17 N:P:K:S) applied at 181kg/ha (75kg K/ha) & incorporated to 7cm with disc harrows. Soil testing prior to planting showed good nutrient status for carrots apart from P which remained a little low even after the superphosphate application. Also, marginal trace element levels indicated a need for monitoring and if necessary applying these during crop development.

Marginal and slight trace element deficiencies recorded in foliage at 10 weeks were treated using Richgro Complete Trace Elements, applied at 100kg/ha ($10 g/m^2$) giving the following: S 11.5kg/ha; Fe 12.0kg/ha; Zn 1.1kg/ha; Ca 3.5kg/ha; Cu 0.5kg/ha; Mn 3.1kg/ha; B 0.1kg/ha; Mg 2.0kg/ha; Mo 0.04kg/ha.

Planting
All seed was hand planted on 23 Jan 2008, to a depth of about 5-10 mm using a seed-tape planter with seed spaced at 1 cm intervals. Despite the close plantings, thinning was not necessary due to poor seed viability.

Irrigation
Irrigation was provided by solid set sprinklers arranged in a square grid pattern with 3.2 metres between risers. Irrigation was applied slightly in excess of requirement to ensure it was not a limiting factor but care was taken to avoid over-watering and leaching of applied nitrogen.

Maintenance
No fungicides were used but the herbicides Linuron® 500 WG + Gesagard® 500 SC applied at 2.2kg/ha + 2.2L/ha respectively (Single jet, flat-fan knapsack sprayer at 250L/ha output) 30 days after planting on 22 Feb 2008 at the 3 leaf stage.

Table 5.1 *– BC0801: Treatment (Nitrogen Application) Details*

NO.	TREATMENT	At Planting (kg N/ha)	Lo-Bi* Urea/3.2 m^2 plot (g)	6 Weeks After Planting (kg N/ha)	Lo-Bi* Urea/3.2 m^2 plot (g)	12 Weeks After Planting (kg N/ha)	Lo-Bi* Urea/3.2 m^2 plot (g)	Total N applied (kg/ha)
1	Untreated	---		---		---		0
2	25 E	25	17.39	---		---		25
3	50 E	50	34.78	---		---		50
4	100 E	100	69.57	---		---		100
5	25 M	---		25	17.39	---		25
6	50 M	---		50	34.78	---		50
7	25 L	---		---		25	17.39	25
8	50 L	---		---		50	34.78	50
9	25 E/M/L	25	17.39	25	17.39	25	17.39	75
10	50 E/M/L	50	34.78	50	34.78	50	34.78	150
11	5 (x10)	5 kg N/ha at sowing and then every 14 days (3.48 g Lo-Bi Urea/plot)						50
12	10 (x10)	10 kg N/ha at sowing and then every 14 days (6.96 g Lo-Bi Urea/plot)						100

*Lo-Biurette Urea = 46% N; E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks).

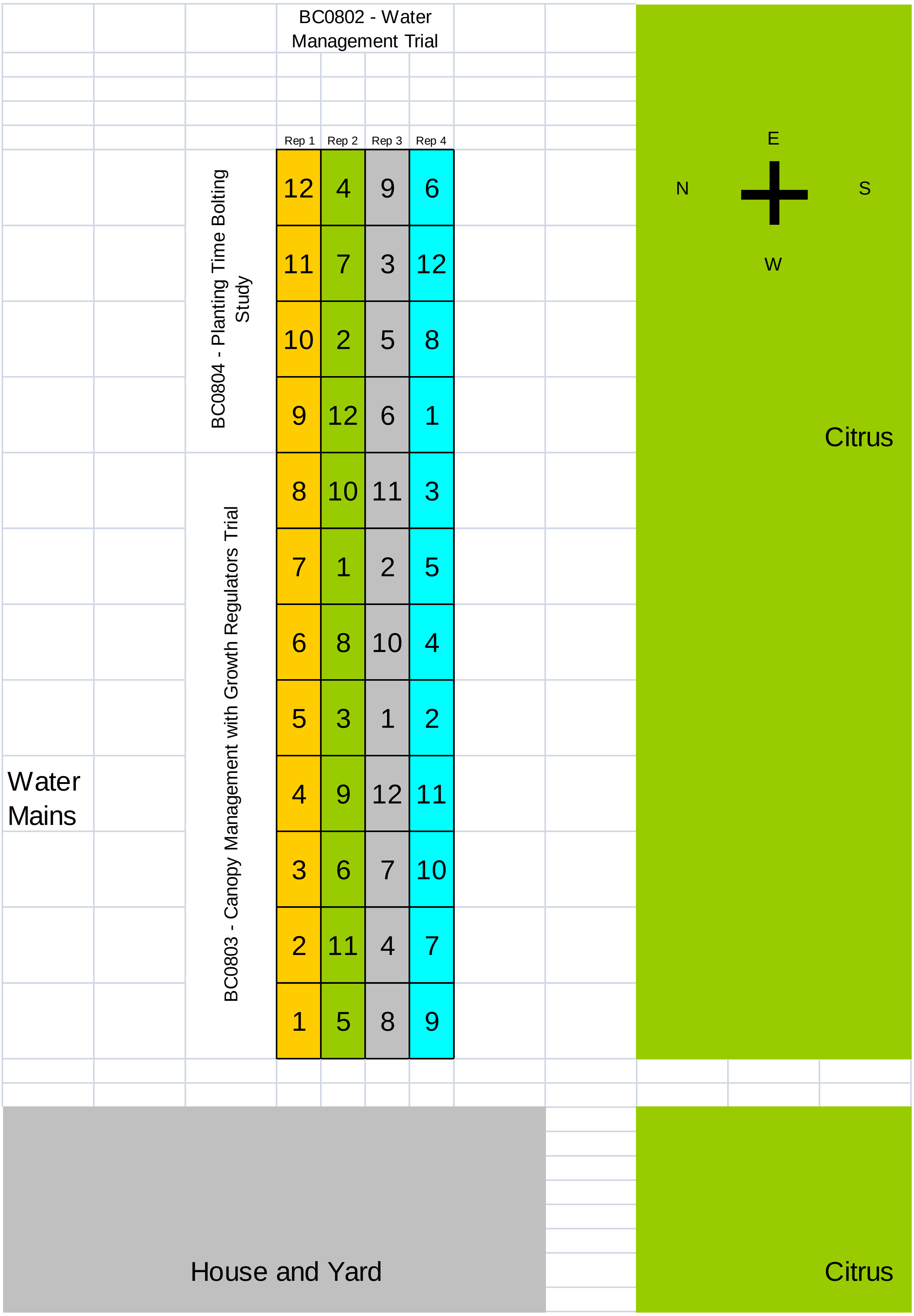
Evaluation:

Photographs were taken at various stages between emergence and harvest. Foliar samples using 10 x YML (youngest mature leaf) were taken from selected plots at 6, 10 & 21 weeks post-planting for complete dry-ash analysis. Harvest was carried out on 16-17 Jun 2008, (145 DAP) by harvesting 1.00m of bed (all 4 carrot rows). Over following two days samples were assessed for bolting, carrot numbers, weights, shapes, cracking, deformities or other anomalies. After taking photographs of whole samples, entire plot yields were packed in plastic bags and cool stored. They were cool stored for up to several weeks at 4° C, before being juiced at SDS Beverages in Merbein, with whole replicates taken and juiced the same day. A 500 mL sample of juice was kept from each sample, frozen and subsequently analysed in SDS's Merbein laboratory for Brix using a refractometer and anthocyanin content using an absorbance spectrophotometer.

Statistical Analyses:

In all tables shown, vertical bars aligned in the same column indicate means that are NOT SIGNIFICANTLY DIFFERENT (LSD, P=0.05). Means followed by "-" failed Bartlett's Chi-squared Test for Homogeneity of Variance and attempts to rectify this with transformations were NOT successful (P=0.05). NSAP indicates no statistical analysis performed. Blue vertical bars indicate LSD results based on successfully transformed data BUT the numbers they follow are original.

***Figure 5.1** – BC0801: Trial layout*



Results (BC0801 – Dareton, NSW, 2008)

Table 5.2. *BC0801: Carrot Yield Components – Total & Harvestable Yields (t/ha), classified by Nitrogen Treatment*

Nitrogen Applied (kg) & Timing*	TOTAL Yield (t/ha)	Nitrogen Applied (kg) & Timing*	YIELD 21+mm (t/ha)	Nitrogen Applied (kg) & Timing*	YIELD 26+mm (t/ha)
50 M	58.828 I	**50 M**	58.548 I	**50 M**	57.700 I
50 L	55.044 I	**50 L**	54.255 I	**50 L**	53.384 I
25 E	52.578 I	**25 E**	52.063 I	**25 E**	51.125 I
25 E/M/L	52.341 I	**25 E/M/L**	51.734 I	**25 E/M/L**	50.289 I
25 M	51.091 I	**100 E**	50.434 I	**25 L**	49.386 I
25 L	51.070 I	**25 M**	50.366 I	**100 E**	49.252 I
100 E	50.959 I	**25 L**	50.323 I	**25 M**	49.097 I
5 (x10)	50.183 I	**5 (x10)**	49.442 I	**5 (x10)**	48.264 I
10 (x10)	49.623 I	**50 E/M/L**	48.958 I	**50 E/M/L**	48.022 I
50 E/M/L	49.463 I	**10 (x10)**	48.809 I	**10 (x10)**	47.755 I
Untreated	48.923 I	**Untreated**	48.225 I	**Untreated**	47.453 I
50 E	42.952 I	**50 E**	42.302 I	**50 E**	41.142 I

*E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks); (x10) = 10 fortnightly applications.

Table 5.3. *BC0801: Carrot Yield Components – Total & Harvestable Yields (Numbers of Carrots), classified by Nitrogen Treatment*

Nitrogen Applied (kg) & Timing*	TOTAL No./ha	Nitrogen Applied (kg) & Timing*	No. 21+mm/ha	Nitrogen Applied (kg) & Timing*	No. 26+mm/ha
50 L	595,313 I	**50 L**	492,188 I	**50 L**	454,688 I
Untreated	535,938 I	**50 M**	464,063 I	**Untreated**	425,000 I
25 E/M/L	531,250 I	**25 E**	460,938 I	**50 M**	425,000 I
25 E	529,688 I	**Untreated**	459,375 I	**25 E**	418,750 I
100 E	512,500 I	**25 E/M/L**	457,813 I	**25 E/M/L**	403,125 I
25 L	510,938 I	**100 E**	446,875 I	**100 E**	400,000 I
5 (x10)	510,938 I	**25 M**	443,750 I	**25 L**	395,313 I
25 M	509,375 I	**25 L**	434,375 I	**25 M**	392,188 I
50 M	506,250 I	**5 (x10)**	421,875 I	**10 (x10)**	382,813 I
50 E	479,688 I	**10 (x10)**	415,625 I	**50 E/M/L**	376,563 I
50 E/M/L	478,125 I	**50 E/M/L**	414,063 I	**5 (x10)**	365,625 I
10 (x10)	476,563 I	**50 E**	396,875 I	**50 E**	346,875 I

*E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks); (x10) = 10 fortnightly applications.

Table 5.4. *BC0801: Carrot Yield Components – Average Plant Spacing (mm) & Undersize Yields (t/ha), classified by Nitrogen Treatment*

Nitrogen Applied (kg) & Timing*	Av. Plant Spacing (mm)	Nitrogen Applied (kg) & Timing*	YIELD <21mm (t/ha)	Nitrogen Applied (kg) & Timing*	YIELD 21-25mm (t/ha)
50 E	54.6 I	**10 (x10)**	0.814 I	**25 E/M/L**	1.445 I
10 (x10)	53.7 I	**50 L**	0.789 I	**25 M**	1.269 I
50 E/M/L	53.1 I	**25 L**	0.747 I	**100 E**	1.183 I
5 (x10)	51.8 I	**5 (x10)**	0.741 I	**5 (x10)**	1.178 I
50 M	49.7 I	**25 M**	0.725 I	**50 E**	1.159 I
25 L	49.5 I	**Untreated**	0.698 I	**10 (x10)**	1.055 I
25 M	49.4 I	**50 E**	0.650 I	**25 E**	0.938 I
100 E	49.3 I	**25 E/M/L**	0.606 I	**25 L**	0.938 I
25 E/M/L	47.9 I	**100 E**	0.525 I	**50 E/M/L**	0.936 I
25 E	47.9 I	**25 E**	0.516 I	**50 L**	0.870 I
Untreated	47.3 I	**50 E/M/L**	0.505 I	**50 M**	0.848 I
50 L	43.0 I	**50 M**	0.280 I	**Untreated**	0.772 I

*E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks); (x10) = 10 fortnightly applications.

Table 5.5. *BC0801: Carrot Yield Components – Undersize Yields (Numbers of Carrots), classified by Nitrogen Treatment*

Nitrogen Applied (kg) & Timing*	No. <21mm/ha	Nitrogen Applied (kg) & Timing*	No. 21-25mm/ha
50 L	103,125 I	**5 (x10)**	56,250 I
5 (x10)	89,063 I	**25 E/M/L**	54,688 I
50 E	82,813 I	**25 M**	51,563 I
Untreated	76,563 I	**50 E**	50,000 I
25 L	76,563 I	**100 E**	46,875 I
25 E/M/L	73,438 I	**25 E**	42,188 I
25 E	68,750 I	**50 M**	39,063 I
100 E	65,625 I	**25 L**	39,063 I
25 M	65,625 I	**50 L**	37,500 I
50 E/M/L	64,063 I	**50 E/M/L**	37,500 I
10 (x10)	60,938 I	**Untreated**	34,375 I
50 M	42,188 I	**10 (x10)**	32,813 I

*E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks); (x10) = 10 fortnightly applications.

__Figure 5.2.__ BC0801: Carrot Yield Components – Total & Harvestable Yields (t/ha), classified by Nitrogen Treatment

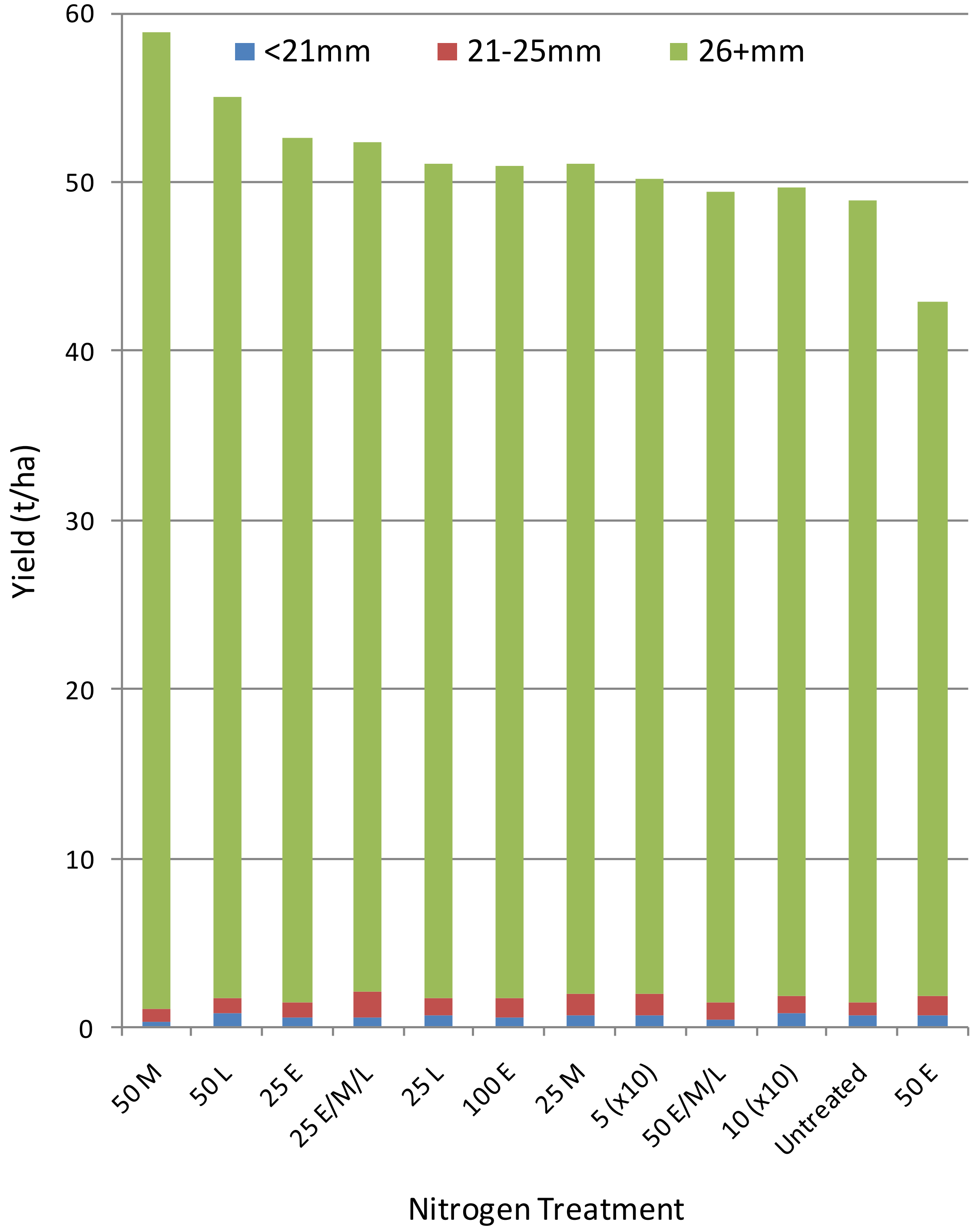


Table 5.6. *BC0801: Canopy Yield Components – Canopy Yields (t/ha) & Canopy/Carrot Yield Ratios, classified by Nitrogen Treatment*

Nitrogen Applied (kg) & Timing*	Canopy Yield (t/ha)	Nitrogen Applied (kg) & Timing*	Canopy/Carrot Weight Ratio
25 E/M/L	41.269 I	**25 L**	0.80 I
25 L	40.736 I	**25 E/M/L**	0.78 I
50 M	39.788 I	**10 (x10)**	0.73 I
50 L	38.795 I	**50 E/M/L**	0.73 I
10 (x10)	35.844 I	**50 L**	0.70 I
5 (x10)	35.517 I	**50 M**	0.69 I
50 E/M/L	34.973 I	**5 (x10)**	0.69 I
25 E	33.553 I	**50 E**	0.67 I
100 E	33.194 I	**100 E**	0.64 I
25 M	31.894 I	**25 E**	0.63 I
50 E	30.473 I	**25 M**	0.61 I
Untreated	26.323 I	**Untreated**	0.51 I

*E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks); (x10) = 10 fortnightly applications

Table 5.7. *BC0801: Canopy Vigour – Average, Highest & Lowest Relative Canopy Vigour (%) from each Plot 114 days After Planting, classified by Nitrogen Treatment*

Nitrogen Applied (kg) & Timing*	Av. Canopy Vigour (%)	Nitrogen Applied (kg) & Timing*	Highest Canopy Vigour (%)	Nitrogen Applied (kg) & Timing*	Lowest Canopy Vigour (%)
10 (x10)	94 I	**10 (x10)**	98 I	**10 (x10)**	89 I
25 L	91 I	**25 L**	96 I	**50 E/M/L**	83 I
25 E/M/L	91 I	**25 E/M/L**	95 I	**50 L**	81 I
50 E/M/L	89 I	**50 E/M/L**	94 I	**50 M**	79 I
5 (x10)	87 I	**100 E**	93 I	**25 E/M/L**	78 I
50 L	87 I	**50 M**	91 I	**25 L**	75 I
50 M	86 I	**50 L**	91 I	**5 (x10)**	75 I
100 E	84 I	**5 (x10)**	91 I	**25 M**	70 I
25 M	81 I	**25 M**	86 I	**25 E**	69 I
25 E	79 I	**25 E**	85 I	**100 E**	69 I
50 E	74 I	**50 E**	83 I	**50 E**	60 I
Untreated	71 I	**Untreated**	81 I	**Untreated**	58 I

*E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks); (x10) = 10 fortnightly applications.

Figure 5.3. *BC0801: Total Plant, Carrot & Canopy Yields (t/ha), classified by Nitrogen Treatment*

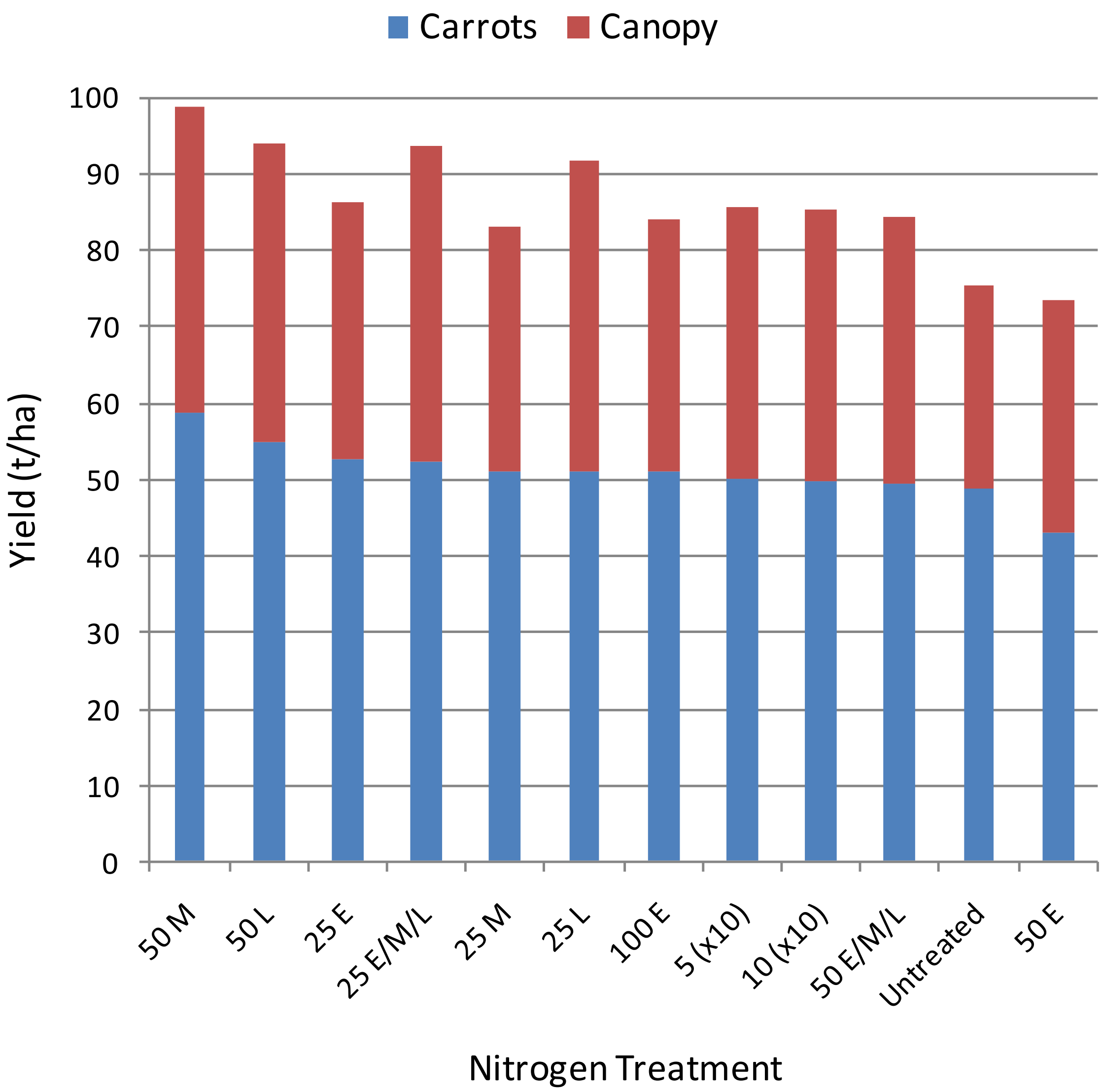


Table 5.8. *BC0801: Average Carrots Weights based on Total & Harvestable Yields (g), classified by Nitrogen Treatment*

Nitrogen Applied (kg) & Timing*	Av. Carrot Weight for Total Yield (g)	Nitrogen Applied (kg) & Timing*	Av. Carrot Weight for Carrots 21+mm (g)	Nitrogen Applied (kg) & Timing*	Av. Carrot Weight for Carrots 26+mm (g)
50 M	116 I	**50 M**	126 I	**50 M**	135 I
10 (x10)	107 I	**5 (x10)**	120 I	**5 (x10)**	133 I
50 E/M/L	104 I	**10 (x10)**	119 I	**50 E/M/L**	128 I
5 (x10)	103 I	**50 E/M/L**	119 I	**25 L**	126 I
25 E	102 I	**25 L**	117 I	**10 (x10)**	126 I
25 M	101 I	**25 E**	116 I	**25 E/M/L**	125 I
25 L	100 I	**25 M**	114 I	**25 M**	125 I
25 E/M/L	100 I	**25 E/M/L**	114 I	**25 E**	125 I
100 E	99 I	**100 E**	113 I	**100 E**	123 I
50 L	95 I	**50 L**	111 I	**50 L**	118 I
Untreated	95 I	**Untreated**	108 I	**50 E**	118 I
50 E	90 I	**50 E**	107 I	**Untreated**	115 I

*E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks); (x10) = 10 fortnightly applications.

Table 5.9. *BC0801: Yields of Different Shaped Carrots (g), classified by Nitrogen Treatment*

Nitrogen Applied (kg) & Timing*	Short Carrot Yield (t/ha)	Nitrogen Applied (kg) & Timing*	Normal Carrot Yield (t/ha)	Nitrogen Applied (kg) & Timing*	Long Carrot Yield (t/ha)
10 (x10)	4.391 I	**50 L**	19.409 I	**25 M**	16.358 I
5 (x10)	3.261 I	**Untreated**	18.988 I	**100 E**	14.694 I
25 E/M/L	2.994 I	**25 E**	18.984 I	**50 M**	11.431 I
50 M	2.900 I	**100 E**	17.775 I	**25 L**	11.259 I
100 E	2.466 I	**25 M**	17.289 I	**5 (x10)**	10.677 I
50 E/M/L	2.241 I	**50 E/M/L**	16.111 I	**Untreated**	10.239 I
Untreated	2.192 I	**50 M**	15.950 I	**25 E/M/L**	10.195 I
25 M	1.878 I	**10 (x10)**	15.923 I	**50 E**	10.153 I
25 E	1.741 I	**50 E**	14.694 I	**25 E**	8.466 I
50 L	1.559 I	**25 E/M/L**	14.605 I	**50 L**	7.933 I
25 L	0.903 I	**25 L**	14.475 I	**10 (x10)**	6.616 I
50 E	0.564 I	**5 (x10)**	10.006 I	**50 E/M/L**	6.347 I

*E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks); (x10) = 10 fortnightly applications.

__Table 5.10.__ BC0801: Yields of Different Shaped Carrots (Numbers), classified by Nitrogen Treatment

Nitrogen Applied (kg) & Timing*	Short Carrots (26+mm)/ha	Nitrogen Applied (kg) & Timing*	Normal Carrots (26+mm)/ha	Nitrogen Applied (kg) & Timing*	Long Carrots (26+mm)/ha
10 (x10)	54,688 I	**50 L**	242,188 I	**100 E**	71,875 I
Untreated	39,063 I	**100 E**	204,688 I	**25 M**	71,875 I
50 M	35,938 I	**Untreated**	196,875 I	**50 M**	62,500 I
100 E	31,250 I	**25 L**	179,688 I	**25 E/M/L**	62,500 I
5 (x10)	31,250 I	**50 E/M/L**	179,688 I	**50 E**	57,813 I
25 M	28,125 I	**10 (x10)**	176,563 I	**25 L**	56,250 I
25 E	21,875 I	**25 M**	175,000 I	**5 (x10)**	56,250 I
50 E/M/L	20,313 I	**25 E**	171,875 I	**Untreated**	54,688 I
25 E/M/L	18,750 I	**25 E/M/L**	170,313 I	**25 E**	39,063 I
25 L	14,063 I	**50 E**	167,188 I	**50 L**	37,500 I
50 L	10,938 I	**50 M**	167,188 I	**10 (x10)**	31,250 I
50 E	7,813 I	**5 (x10)**	129,688 I	**50 E/M/L**	25,000 I

*E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks); (x10) = 10 fortnightly applications.

__Table 5.11.__ BC0801: Yields of Forked Carrots (t/ha & Numbers), classified by Nitrogen Treatment

Nitrogen Applied (kg) & Timing*	26+mm Forked Carrot Yield (t/ha)	Nitrogen Applied (kg) & Timing*	26+mm Forked Carrots/ha
50 M	27.419 I	**25 E**	185,938 I
50 L	24.483 I	**50 L**	164,063 I
5 (x10)	24.320 I	**50 M**	159,375 I
50 E/M/L	23.323 I	**25 E/M/L**	151,563 I
25 L	22.748 I	**50 E/M/L**	151,563 I
25 E/M/L	22.495 I	**5 (x10)**	148,438 I
25 E	21.934 I	**25 L**	145,313 I
10 (x10)	20.825 I	**Untreated**	134,375 I
Untreated	16.034 I	**10 (x10)**	120,313 I
50 E	15.731 I	**25 M**	117,188 I
100 E	14.317 I	**50 E**	114,063 I
25 M	13.572 I	**100 E**	92,188 I

*E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks); (x10) = 10 fortnightly applications.

Figure 5.4. *BC0801: Harvestable Carrot Yield Components(26+mm) – Forked, Short, Normal and Long Shapes (t/ha), classified by Nitrogen Treatment*

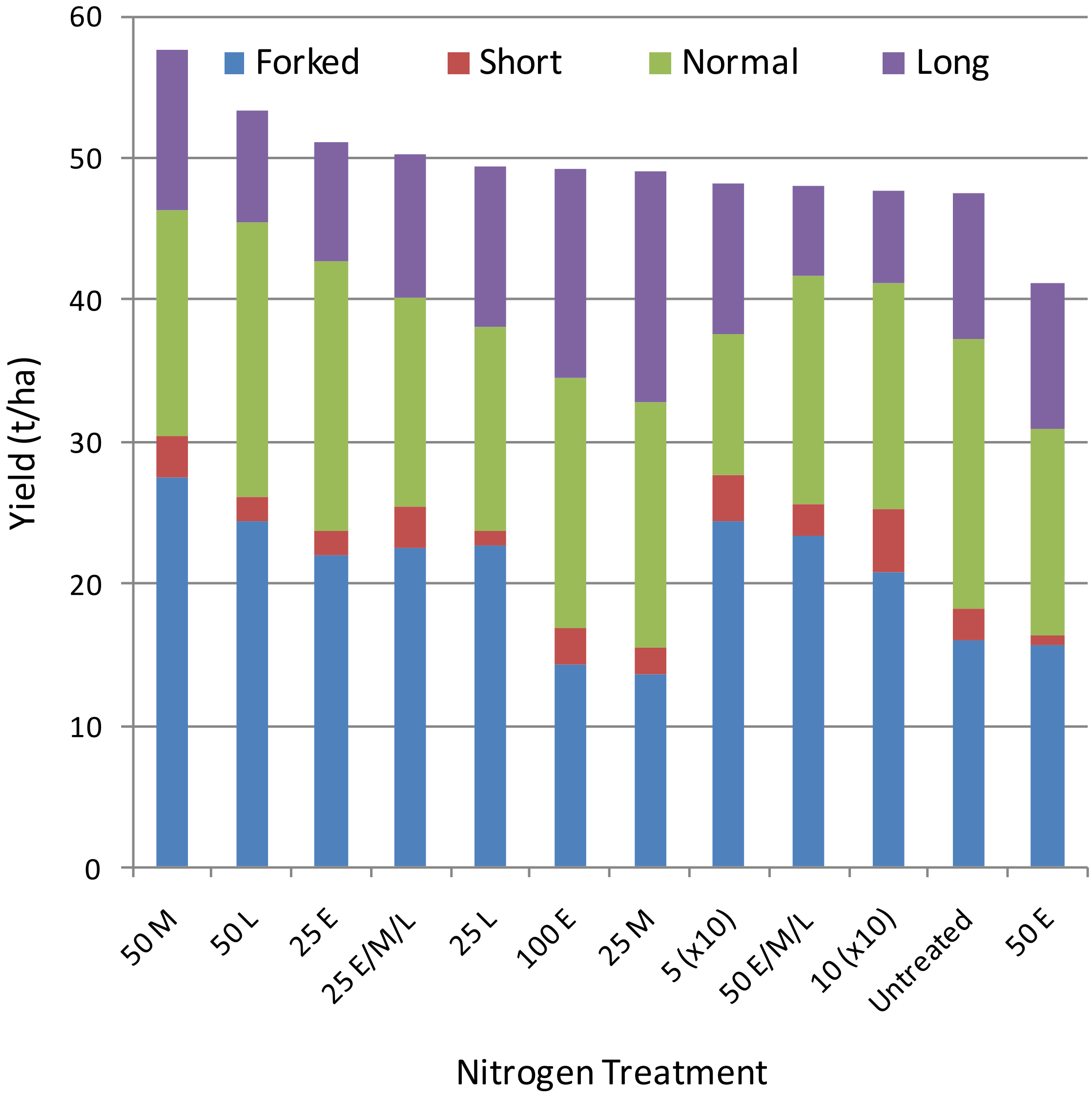


Table 5.12. *BC0801: Brix (°Br), Absorbance (@538nm) & Anthocyanins (mg%@8.0°Br), classified by Nitrogen Treatment*

Nitrogen Applied (kg) & Timing*	Brix (°Br)	Nitrogen Applied (kg) & Timing*	Absorbance (@538nm)	Nitrogen Applied (kg) & Timing*	Anthocyanins (mg%@8.0°Br)
25 E	10.0 I	**25 E**	0.326 I	**25 E**	36.1 I
Untreated	9.8 I	**5 (x10)**	0.310 I	**5 (x10)**	33.6 I
100 E	9.7 I	**25 M**	0.308 I	**25 M**	31.8 I
25 M	9.7 I	**50 M**	0.284 I	**50 M**	31.7 I
25 L	9.7 I	**10 (x10)**	0.282 I	**10 (x10)**	29.2 I
50 M	9.6 I	**Untreated**	0.256 I	**Untreated**	29.0 I
50 E/M/L	9.6 I	**100 E**	0.232 I	**100 E**	26.3 I
5 (x10)	9.6 I	**25 E/M/L**	0.222 I	**25 E/M/L**	23.9 I
25 E/M/L	9.3 I	**50 L**	0.211 I	**50 L**	22.9 I
50 L	9.2 I	**25 L**	0.205 I	**25 L**	21.1 I
10 (x10)	8.9 I	**50 E**	0.192 I	**50 E**	19.7 I
50 E	8.9 I	**50 E/M/L**	0.186 I	**50 E/M/L**	19.1 I

*E = Early (0 weeks); M = Mid-establishment (6 weeks); L = Late establishment (12 weeks); (x10) = 10 fortnightly applications.

Figure 5.5. *BC0801: Relationship between Foliar Nitrogen (%) & Foliar Nitrate (ppm) from Youngest Mature Leaf samples collected at 6-21 weeks, classified by Nitrogen Treatment*

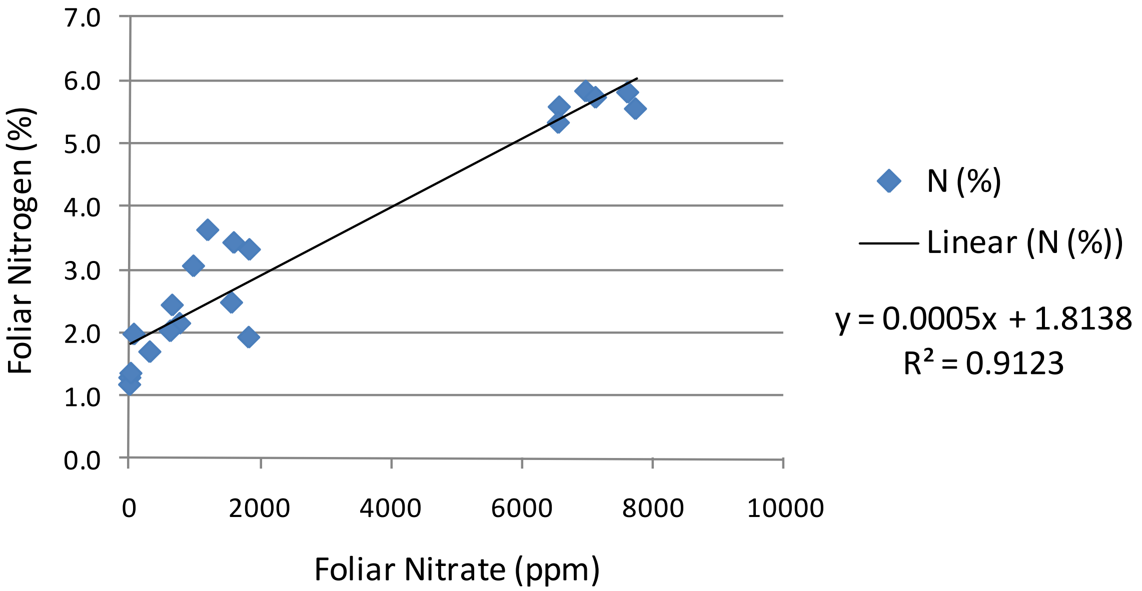


Table 5.13. *BC0801: Foliar Nutrient Levels from Complete Dry-ash Analyses of Selected Treatments, 6 Weeks After Planting*

Treatment	Nitrate (ppm)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Mo (ppm)	Zn (ppm)	Na (%)	Cl (%)
Untreated	6979	5.82	0.62	5.80	2.33	0.33	0.19	29	6.3	168	40	1.07	30	0.23	1.63
25 E	6574	5.57	0.65	5.96	2.35	0.35	0.23	27	6.5	185	49	1.43	33	0.25	1.75
50 E	7621	5.80	0.64	5.95	2.31	0.34	0.18	24	6.2	180	45	1.26	31	0.25	1.36
100 E	7129	5.72	0.64	6.00	2.20	0.32	0.19	19	4.9	155	43	0.97	30	0.22	0.99
5 (x10)	6560	5.32	0.62	6.07	2.14	0.34	0.16	25	6.5	173	47	1.08	31	0.23	1.59
10 (x10)	7740	5.54	0.58	5.92	2.14	0.32	0.16	23	5.5	171	48	0.91	31	0.23	1.06
Guide		**2.00**	**0.20**	**2.50**	**1.40**	**0.20**	**0.20**	**30**	**5.0**	**50**	**30**	**0.50**	**25**	**<0.5**	**<1.0**

High | Normal | Slightly Low | Low

Table 5.14. *BC0801: Foliar Nutrient Levels from Complete Dry-ash Analyses of Selected Treatments, 10 Weeks After Planting*

Treatment	Nitrate (ppm)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Mo (ppm)	Zn (ppm)	Na (%)	Cl (%)
Untreated	978	3.05	0.51	5.05	1.42	0.21	0.41	42	5.6	244	33	0.67	25	0.25	1.81
50 E/M/L	1833	3.31	0.51	5.38	1.14	0.19	0.37	37	3.7	208	29	0.37	23	0.22	1.49
5 (x10)	1196	3.62	0.48	5.29	1.17	0.20	0.43	36	5.5	201	31	0.57	20	0.25	1.94
10 (x10)	1596	3.42	0.51	5.18	1.26	0.21	0.41	37	5.2	219	32	0.63	24	0.27	1.89
Guide		**2.00**	**0.20**	**2.50**	**1.40**	**0.20**	**0.20**	**30**	**5.0**	**50**	**30**	**0.50**	**25**	**<0.5**	**<1.0**

High | Normal | Slightly Low | Low

Table 5.15. *BC0801: Foliar Nutrient Levels from Complete Dry-ash Analyses of Selected Treatments, 21 Weeks After Planting*

Treatment	Nitrate (ppm)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Mo (ppm)	Zn (ppm)	Na (%)	Cl (%)
Untreated	551	1.72	0.36	4.96	1.67	0.22	0.37	47	3.8	84	26	0.80	22	0.41	2.48
50 E/M/L	327	1.80	0.36	4.68	1.52	0.21	0.29	46	3.8	75	24	1.04	21	0.37	2.43
10 (x10)	742	2.00	0.37	5.18	1.26	0.20	0.24	43	3.7	60	22	0.43	23	0.41	2.56
Guide		**2.00**	**0.20**	**2.50**	**1.40**	**0.20**	**0.20**	**30**	**5.0**	**50**	**30**	**0.50**	**25**	**<0.5**	**<1.0**

High | Normal | Slightly Low | Low

No Nutrient Levels were significantly different (LSD, Pr=0.95) between N Treatments

Table 5.16. *BC0801: Analysis of Irrigation Water, sampled 17 Apr 2008, used throughout the trial.*

Nitrate N (mg/l) <0.500
Potassium (mg/l) 1.00
Ammonia N (mg/l) <1.00
Phosphorus (mg/l) <1.000
Chloride (mg/l) 36 **High foliar Cl was the main reason for conducting test but NOT particularly high**
Molybdenum (mg/l) <0.01
E.C. (dS/M) 0.220
Bicarbonate (mg/l) 39
pH 7.0
Calcium (mg/l) 7
Boron (mg/l) <0.02
Manganese (mg/l) <0.05
Copper (mg/l) <0.01
Magnesium (mg/l) 5
Sulphur (mg/l) 4.0
Zinc (mg/l) <0.02
Sodium (mg/l) 11.00
Iron (mg/l) <0.100

Table 5.17. *BC0801: Analysis of Carrot Tissue, sampled from Treatment 12 (10 (x10)), 21 Weeks After Planting, used throughout the trial.*

Analysis	T12 R1	T12 R2	T12 R3	T12 R4	Average	Std Error
Moisture (%)	87.9	88.0	87.4	88.3	**87.90**	0.19
Cl (%)	0.77	0.66	0.85	0.70	**0.75**	0.04
Na (%)	0.320	0.350	0.150	0.100	**0.230**	0.06
Fe (ppm)	31	30	29	15	**26.3**	3.77
Cu (ppm)	2.1	1.9	2.4	1.4	**2.0**	0.21
B (ppm)	30	29	29	15	**26**	3.59
Zn (ppm)	16	19	15	10	**15**	1.87
Mn (ppm)	16	13	11	7	**12**	1.89
S (%)	0.12	0.13	0.10	0.13	**0.12**	0.01
Mg (%)	0.13	0.13	0.10	0.06	**0.11**	0.02
Ca (%)	0.34	0.36	0.32	0.21	**0.31**	0.03
K (%)	4.41	4.21	3.47	2.29	**3.60**	0.48
P (%)	0.46	0.46	0.36	0.21	**0.37**	0.06
NO_3-N	1108	886	1	1130	**781**	265.86
Mo (ppm)	0.05	0.05	0.05	0.05	**0.05**	0.00
N (%)	1.86	1.78	0.81	1.89	**1.59**	0.26

Table 5.18. *BC0801: Estimated Nutrient Removal by a 49.6 t/ha LX3632 carrot crop (using Treatment 12 = 10 (x10) as a reference).*

Analysis	Carrots (Dry Ash)	Carrots (% of Fresh Weight)	Leaves (Dry Ash)	Leaves (% of Fresh Weight)	kg/ha used by 49623kg /ha carrots	kg/ha used by 35844kg /ha canopy	Total Crop Use (kg/ha)	Crop Use/tonne of Total Plant Yield (kg)	Crop Use/tonne of Total Carrot Yield (kg)
Cl (%)	0.75	0.090145	2.56	0.256000	44.733	91.761	136.493293	1.597	**2.751**
Na (%)	0.230	0.027830	0.410	0.041000	13.810	14.696	28.506121	0.334	**0.574**
Fe (ppm)	26.3	0.000318	60	0.000600	0.158	0.215	0.372679	0.004	**0.008**
Cu (ppm)	2.0	0.000024	3.7	0.000037	0.012	0.013	0.025078	0.000	**0.001**
B (ppm)	26	0.000312	43	0.000433	0.155	0.155	0.309638	0.004	**0.006**
Zn (ppm)	15	0.000182	23	0.000228	0.090	0.082	0.171611	0.002	**0.003**
Mn (ppm)	12	0.000142	22	0.000220	0.071	0.079	0.149408	0.002	**0.003**
S (%)	0.12	0.014520	0.24	0.024000	7.205	8.603	15.807820	0.185	**0.319**
Mg (%)	0.11	0.012705	0.20	0.020000	6.305	7.169	13.473402	0.158	**0.272**
Ca (%)	0.31	0.037208	1.26	0.126000	18.463	45.163	63.626918	0.744	**1.282**
K (%)	3.60	0.434995	5.18	0.518000	215.858	185.672	401.529489	4.698	**8.092**
P (%)	0.37	0.045073	0.37	0.037000	22.366	13.262	35.628607	0.417	**0.718**
NO_3-N (ppm)	781	0.009453	742	0.007420	4.691	2.660	7.350549	0.086	**0.148**
Mo (ppm)	0.05	0.000001	0.43	0.000004	0.000	0.002	0.001842	0.000	**0.000**
N (%)	1.59	0.191785	2.00	0.200000	95.169	71.688	166.857471	1.952	**3.363**
Note: Carrots are 87.9% moisture & Leaves are assumed to be 90% moisture									

Table 5.19. *BC0801: Soil Nutrient Levels from Selected Areas (0-30cm), 0, 6 & 8 Weeks After Planting*

Analysis	Guide	Pre-Plant. Analysed 13/03/2008	Area of Poor Emergence. Collected at 6 Weeks (07/03/2008). Analysed 13/03/2008	Untreated Area Inside Trial. Collected at 8 weeks (19/03/2008). Analysed 27/03/2008	Untreated Area Outside Trial. Collected at 8 Weeks (19/03/2008). Analysed 27/03/2008
pH [H_2O]	5.6	7.5	8.0	7.4	8.1
pH [$CaCl_2$]	5.0	7.2	7.5	7.0	7.8
Organic Matter (%)	3.0	0.8	0.7	0.7	0.6
CEC (meq/100g)	12.0	9.6	9.5	8.9	10.3
EC (dS/m)	0.90	0.16	0.13	0.09	0.08
NO_3-N (ppm)	15.0	42.4	25.2	13.4	2.4
NH_4-N (ppm)		1.6	1.90	<1.0	1.10
P [Olsen] (ppm)	35	16	28	10	9
K (meq/100g)	0.70	1.22	0.98	1.08	0.94
Ca (meq/100g)	6.00	6.48	7.06	5.57	7.42
Mg (meq/100g)	1.00	1.70	1.26	2.06	1.76
S (ppm)	8	12	15	7	5
B (ppm)	1.0	1.1	1.1	1.1	0.9
Cu (ppm)	2.5	1.3	1.4	0.9	0.8
Fe (ppm)	5	10	13	10	11
Mn (ppm)	5.0	11.1	8.0	14.7	12.8
Zn (ppm)	5.0	2.3	3.1	1.4	1.5
Al (meq/100g)	1.00	0.06	0.07	<0.02	<0.02
Na (meq/100g)	0.3	0.1	0.1	0.2	0.2
Cl (ppm)	200	16	8	14	14
Ca base saturation (%)	<75.0	67.6	74.3	62.3	71.8
K base saturation (%)	<5.0	12.7	10.3	12.1	9.1
Mg base saturation (%)	<15.0	17.7	13.3	23.0	17.0
Na base saturation (%)	<2.0	1.3	1.4	2.5	1.9
Ca:Mg Ratio	2.5	3.8	5.6	2.7	4.2
Testure		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
Colour		Brown	Brown	Brown	Brown
K (ppm)				422.00	368.00
Mg (ppm)				249.00	213.00
Al base saturation (%)		0.6	0.7	0.1	0.2
Lime Requirement (t/ha)		<0.50	<0.50	<0.50	<0.50
Al (ppm)				<2.0	<2.0
Ca (ppm)				1114.00	1484.00
Na (ppm)				51.00	46.00

High
Normal
Slightly Low
Low
Very Low

Discussion (BC0801 – Dareton, NSW, 2008)

A wide range of parameters were measured. None showed any clear relationship to application timings or levels of N applied. These results are highly consistent with a previous study (Pettipas *et al*, 2003) that showed a very poor relationship between applied nitrogen, foliar N and nitrate levels in leaf tissue and carrot yield and quality.

Total & Harvestable Yields by Weight (Table 5.2)
There were no significant treatment differences and no discernable trends associated with application timings or total amounts of N applied. This was true whether total yield or harvestable yield based on a 21mm or 26mm minimum shoulder width was imposed.

Total & Harvestable Yields by Number (Table 5.3)
There were no significant treatment differences and no discernable trends associated with application timings or total amounts of N applied. This was true whether total carrot numbers or harvestable carrot numbers based on a 21mm or 26mm minimum shoulder width was imposed.

Undersize Yields by Weight (Table 5.4) & Number (Table 5.5)
There were no significant treatment differences and no discernable trends associated with application timings or total amounts of N applied. This was true for both yields and carrot numbers in both of the undersize categories.

Yield – All Components Summed by Weight (Figure 5.2)
This figure shows that yields of carrots <26mm only accounted for about 5% or less, of total yields in all cases.

Canopy Yields & Canopy/Carrot Weight Ratios (Table 5.6 & Figure 5.3)
There were no significant treatment differences associated with application timings or total amounts of N applied. There was a weak trend showing higher canopy weights and canopy/carrot weight ratios to be associated with later applications of N.

Canopy Vigour 114 Days After Planting (Table 5.7)
There were no significant treatment differences associated with application timings or total amounts of N applied. There was a weak trend showing higher canopy weights and canopy/carrot weight ratios to be associated with later applications of N.

Average Carrot Weights (Table 5.8)
There were no significant treatment differences associated with application timings or total amounts of N applied. This was true whether total yields or harvestable carrot yields based on a 21mm or 26mm minimum shoulder width were imposed. However, there was a weak trend toward higher carrot weights from later or higher rates of N applied.

Carrot Shapes (Tables 5.9 & 5.10 & Figure 5.4)
Carrots in the 26+mm class were sorted into groups based on whether they were unusually long & tapering, particularly short and broad, normal or forked. There were no significant treatment differences and no discernable trends associated with application timings or total amounts of N applied. This was true whether yields were based on total weights or numbers of carrots in the 26+mm category.

Forking (Table 5.11)
There were no significant treatment differences and no discernable trends associated with application timings or total amounts of N applied. This was true whether total yields were based on total weights or numbers of carrots in the 26+mm category.

Brix, Absorbance & Anthocyanin Content (Table 5.12)
There were no significant treatment differences and no discernable trends associated with application timings or total amounts of N applied.

Average Plant Spacing (Table 5.4)
Av. Plant spacings ranged from 43-55 mm and were not significantly different, indicating all other comparisons were valid and not affected by this factor. The highest, lowest and average figures were used to capture the within plot variation in canopy vigour seen in this trial.

Bolting
Bolting was virtually insignificant with only a few plants in the entire trial showing signs of late season bolting. No yield adjustments were required to account for this factor.

Nutrient Use & Removal (Tables 5.13-5.19 & Figure 5.5)

Nutrient removal (Table 5.18) is based on carrot (Table 5.17) and leaf (Table 5.15) samples taken at harvest from Treatment 12 (a total of 10 fortnightly applications of urea providing 100 kgN/ha for the trial duration or 10kg N/ha /application) which resulted in a 49.6 t/ha total yield.

No treatments showed significantly differing levels of any nutrient, including N (%) & nitrate (ppm), whether 150kg N/ha or none was applied over the cropping cycle.

Nitrogen & Nitrate
A total of 167kg N/ha was used (Table 5.18).

Regardless of how much or when N was applied the foliar results (Tables 5.13-5.15) show a steady decline in foliar N over the entire cropping cycle from a high initial level. Soil nitrate levels (Table 5.19) were adequate from planting until about 6 weeks but rapidly depleted down to very low levels by 8 weeks. Despite this, foliar N levels were high from planting until 10 weeks, when they were still adequate. Only by harvest, at 21 weeks were foliar levels marginal.

These results in conjunction with yield and quality data show black carrots have a strong capacity to extract sufficient N for normal growth even when indicted soil levels are low.

In Figure 5.5, foliar nitrate in the 1-8000 ppm range showed a good linear correlation with Foliar N in the 1.1-5.9% range (R^2=0.91) for all foliar samples taken during the trial.

Phosphorus
A total of 36kg P/ha was used (Table 5.18).

Soil P levels (Table 5.19) indicated low (deficient) levels at 6-8 weeks. However, Tables 5.13-5.15 show a steady decline over the whole growing cycle in foliar P from a high initial level although adequate levels were maintained to harvest.

These results in conjunction with yield and quality data show black carrots have a strong capacity to extract sufficient P for normal growth even when indicted soil levels are low.

Potassium
A total of 402kg K/ha was used (Table 5.18), indicating this to be the most highly depleted element used for growing black carrots.

Soil K levels (Table 5.19) indicate adequate levels at 6-8 weeks. Tables 5.13-5.15 show a steady decline over the whole growing cycle in foliar K from a high initial level with adequate levels were maintained to harvest.

Calcium
A total of 64kg Ca/ha was used (Table 5.18).

Soil Ca levels (Table 5.19) indicated generally adequate levels at 6-8 weeks. Tables 5.13-5.15 show the most intensive foliar depletion from 6-10 weeks when levels nearly halved to marginal/slightly deficient. Foliar levels were seen to stabilize or even recover slightly by 21 weeks, remaining adequate at harvest.

Magnesium
A total of 13kg Mg/ha was used (Table 5.18).

Soil Mg levels (Table 5.19) indicated adequate levels at 6-8 weeks. Tables 5.13-5.15 show adequate Mg for the duration of the trial, with the most intensive foliar depletion from 6-10 weeks when levels dropped by about a third. Foliar levels then stabilized to harvest at 21 weeks.

Sulfur
A total of 16kg S/ha was used (Table 5.18).

Soil S levels (Table 5.19) indicated adequate levels at 6 weeks, depleting to slightly low at 8 weeks. Foliar results were very interesting (Tables 5.13-5.15) showing slightly low levels at 6 weeks but increasing rapidly to high levels by 10 weeks with only a slight decline to still adequate levels by harvest.

Boron
About 310g B/ha was used (Table 5.18). Like S, the key demand time for B was 0-6 weeks.

Soil B levels (Table 5.19) indicated adequate levels at 6-8 weeks. Foliar levels increased steadily (Tables 5.13-5.15) over the duration of the cropping cycle. Levels were slightly low levels at 6 weeks but increased to adequate levels by 10 weeks increasing even further by 21 weeks at harvest.

Copper
Approximately 25g Cu/ha was used (Table 5.18). Copper demand increased with crop age.

Soil Cu levels (Table 5.19) indicated slightly low levels at 6 weeks, declining markedly to low by 8 weeks. Foliar levels decreased steadily (Tables 5.13-5.15) over the duration of the cropping cycle. Levels were adequate at 6 weeks declining but still generally adequate at 10 but further declining to slightly low by harvest.

Iron
Approximately 370g Fe/ha was used (Table 5.18).

Soil Fe levels (Table 5.19) indicated adequate levels at 6-8 weeks. Foliar levels (Tables 5.13-5.15) increased from 6 to 10 weeks but then fell sharply towards harvest, though levels were still adequate.

Manganese
Approximately 150g Mn/ha was used (Table 5.18).

Soil Mn levels (Table 5.19) indicated adequate levels at 6-8 weeks. Foliar levels (Tables 5.13-5.15) declined steadily over the duration of the cropping cycle, with adequate levels at both 6 and 10 weeks but declining to low levels by 21 weeks.

Molybdenum
Approximately 1.8g Mo/ha was used (Table 5.18).

Soil Mo levels (Table 5.19) were not measured. Foliar levels (Tables 5.13-5.15) declined over the duration of the cropping cycle, mainly between 6 and 10 weeks, with adequate levels at both 6 and 10 weeks but declining to marginal levels by 21 weeks.

Zinc
Approximately 170g Zn/ha was used (Table 5.18).

Soil Zn levels (Table 5.19) were low at 6 weeks declining to very low by 8 weeks. Foliar levels (Tables 5.13-5.15) declined steadily over the duration of the cropping cycle, with adequate levels at 6 weeks but declining to marginal levels by 10 weeks and slightly low by 21 weeks.

Sodium
Approximately 29kg Na/ha was accumulated (Table 5.18). Irrigation water showed low Na levels (Table 5.16).

Soil Na levels (Table 5.19) were low at 6 weeks and slightly low by 8 weeks. Foliar analysis (Tables 5.13-5.15) showed no accumulation in the 6-10 week period, with levels well inside in the healthy range. Levels accumulated slightly but remained inside the safe range at 21 weeks.

Chlorine
Approximately 136kg Cl/ha was accumulated (Table 5.18). Irrigation water showed low Cl levels (Table 5.16) with about 3 times more Cl than Na.

Cl is now known to be an essential element (Marchner, 1995), although it is not commonly deficient.

Soil Cl levels (Table 5.19) were very low at 6-8 weeks and based on the low irrigation water levels the same throughout the trial. Despite the low soil and water levels, foliar analysis (Tables 5.13-5.15) showed high levels at all stages of the cropping cycle. In addition, levels steadily accumulated as the crop matured, particularly between 10 and 21 weeks.

Cl levels accumulated as nitrate was used by the growing plant and declined. This is a well established phenomenon related to maintaining osmotic balance (R. Cirocco, pers. comm. 4/5/10). Studies in sugarcane have suggested Cl may be involved in regulating plant water holding capacity and photosynthesis (Calcino, 1994 thru R. Cirocco, pers. comm.).

The high foliar levels showed no clear symptomatic crop problems.

Materials & Methods (BC0703 – Katherine, NT, 2007)

This trial was established mainly to evaluate Katherine as a prospective new climatic production area. Varied rates of N from 0-200kg/ha were also applied at planting as a secondary line of investigation.

Location
This trial was located at the NT DPI Research Station near Katherine, NT (approx: 14° 27′ 56″ S, 132° 18′ 46″ E, elevation 114m) inside a dedicated area worked up managed solely for the purpose of conducting the trial, on a red loamy sand, typical of the region.

Design
Two separate plantings were made 21 days apart. Each planting consisted of a 45m length of bed, separated into 5 plots, each 9.0m long. Beds consisted of two pair-planted rows (4 single rows in total on a 10/40/10) on a single bed 1.6m wide.

Dates
1st Planting 24 May 2007. 2nd Planting 14 Jun 2007.

Base Nutrition, Bed Preparation & Planting
Both plantings were prepared as follows:
Beds were pre-watered for several days before rotary hoeing and applying base fertilizer, gypsum and dolomite. Soil samples were then taken before applying five nitrogen treatments. These were then again rotary hoed to incorporate N treatments. Bed tops were raked flat. Seed was planted using seed tape to a depth of approximately 15mm and exposed tape covered. Irrigation was then applied immediately after planting. All of these activities were performed in a 48 hour period.

Base fertilizer applied to all plots: Muriate of Potash (75kg K/ha), Single Superphosphate + Trace Elements (50kg P/ha), Gypsum (2.5t/ha) & Dolomite (2.5t/ha).

Table 5.20. *BC0703: Soil Nutrient Requirements pre-application of N Treatments, post application of all other fertilizers, from 4 soil samples Tested (0-30 cm)*

Nutrient	Sample 1 Deficiency (kg/ha)	Sample 2 Deficiency (kg/ha)	Sample 3 Deficiency (kg/ha)	Sample 4 Deficiency (kg/ha)	**Average Requirement (kg/ha)**
N	64	131	134	132	**115.3**
P	0	60	46	65	**42.8**
Fe	3.5	3.5	3.5	3.5	**3.50**
Mn	2.5	3.5	2.5	3.5	**3.00**
Zn	0.0	2.5	0.0	2.5	**1.25**
B	0.2	1.5	1.5	1.5	**1.18**

N treatments were applied as Sulphate of Ammonia at **0, 25, 50, 100 & 200 kg N/ha**.

Irrigation
Irrigation was provided by surface laid trickle tape with 10cm spaced emitters running down the centre of each of the paired rows (2 drip lines/bed). Irrigation was applied 1-2 times daily to maintain tensiometer readings in the 5-8kPa at 20cm depth and 10-12kPa at 40cm depth.

Maintenance
No fungicides or herbicides were used. Weeds were removed by hand. Ants nests were removed with Regent® at 3mL/L water using a single jet, knapsack sprayer 28 May 2007.

Evaluation:
Photographs were taken at various stages between emergence and harvest. Soil samples were taken from four sections of the trial area (2 samples/planting time) after all nutrients had been incorporated other than the nitrogen treatments. Foliar samples using whole carrot tops were taken from all plots at 6 & 12 weeks post-planting for complete dry-ash analysis. Harvest was carried out on 01 Oct 2007, (130 & 109 DAP1 & DAP2 respectively) by harvesting 3.00m of bed (all 4 carrot rows) from each plot. Over following two days samples were assessed for carrot numbers, weights, and any anomalies. Sub-samples were packed plastic bags and cool stored at DPI, Darwin. Small wedges from the centre section of these carrots were express couriered to SDS Beverages in Merbein, and juiced within 24 hours of arrival. Samples of juice were immediately analysed in SDS's Merbein laboratory for Brix using a refractometer and anthocyanin content using an absorbance spectrophotometer.

Results (BC0703 – Katherine, NT, 2007)

Table 5.21. *BC0703:* ***Planting 1*** *- Total Yields (t/ha) of Carrots & Canopy, Canopy/Carrot Ratio & Average Carrot Weights (g) 130 Days After Planting, classified by Treatment (Nitrogen applied)*

Nitrogen Applied (kg)	TOTAL Yield Carrot (t/ha)	Nitrogen Applied (kg)	TOTAL Yield Canopy (t/ha)	Nitrogen Applied (kg)	Canopy/ Carrot Ratio	Nitrogen Applied (kg)	Av. Carrot Weight (g)
100	33.333	**200**	24.375	**25**	0.54	**100**	71
200	32.708	**100**	23.177	**0**	0.58	**200**	59
25	21.667	**25**	11.771	**50**	0.64	**25**	39
50	17.292	**50**	11.146	**100**	0.70	**50**	31
0	13.229	**0**	7.708	**200**	0.75	**0**	24
Av.	**23.646**	**Av.**	**15.635**	**Av.**	**0.64**	**Av.**	**45**

Table 5.22. *BC0703:* ***Planting 1*** *– Brix (°Br) & Anthocyanins (mg%@8.0°Br), classified by Treatment (Nitrogen applied)*

Nitrogen Applied (kg)	Brix (°Br)	Nitrogen Applied (kg)	Absorbance (@538nm)	Anthocyanins (mg%@8.0°Br)	Nitrogen Applied (kg)	Av. Carrot Spacing (mm)
200	13.1	**0**	1.198	123.12	**0**	45
25	12.3	**100**	1.002	102.97	**200**	44
100	12.2	**25**	0.863	88.69	**50**	44
50	11.8	**50**	0.610	62.69	**25**	41
0	10.8	**200**	0.542	55.70	**100**	38
Av.	**12.0**	**Av.**	**0.843**	**86.63**	**Av.**	**43**

Table 5.23. *BC0703:* ***Planting 2*** *- Total Yields (t/ha) of Carrots & Canopy, Canopy/Carrot Ratio & Average Carrot Weights (g) 109 Days After Planting, classified by Treatment (Nitrogen applied)*

Nitrogen Applied (kg)	TOTAL Yield Carrot (t/ha)	Nitrogen Applied (kg)	TOTAL Yield Canopy (t/ha)	Nitrogen Applied (kg)	Canopy/ Carrot Ratio	Nitrogen Applied (kg)	Av. Carrot Weight (g)
50	25.938	**200**	29.063	**50**	1.01	**50**	52
200	25.000	**25**	27.188	**0**	1.13	**200**	51
0	22.500	**50**	26.250	**200**	1.16	**0**	41
25	19.688	**0**	25.313	**100**	1.22	**25**	30
100	15.313	**100**	18.750	**25**	1.38	**100**	27
Av.	**21.688**	**Av.**	**25.313**	**Av.**	**1.18**	**Av.**	**40**

Table 5.24. *BC0703:* ***Planting 2*** *– Brix (°Br) & Anthocyanins (mg%@8.0°Br), classified by Treatment (N applied at Planting)*

Nitrogen Applied (kg)	Brix (°Br)	Nitrogen Applied (kg)	Absorbance (@538nm)	Anthocyanins (mg%@8.0°Br)	Nitrogen Applied (kg)	Av. Carrot Spacing (mm)
50	11.8	**0**	0.662	68.03	**200**	47
200	11.5	**50**	0.562	57.78	**0**	45
100	11.5	**200**	0.400	41.10	**50**	44
25	11.3	**100**	0.380	39.05	**100**	43
0	11.2	**25**	0.348	35.76	**25**	41
Av.	**11.5**	**Av.**	**0.470**	**48.34**	**Av.**	**44**

Figure 5.6. *BC0703:* ***Planting 1*** *- Relationship between Carrot & Canopy Yields (t/ha) & N Applied (kg/ha)*

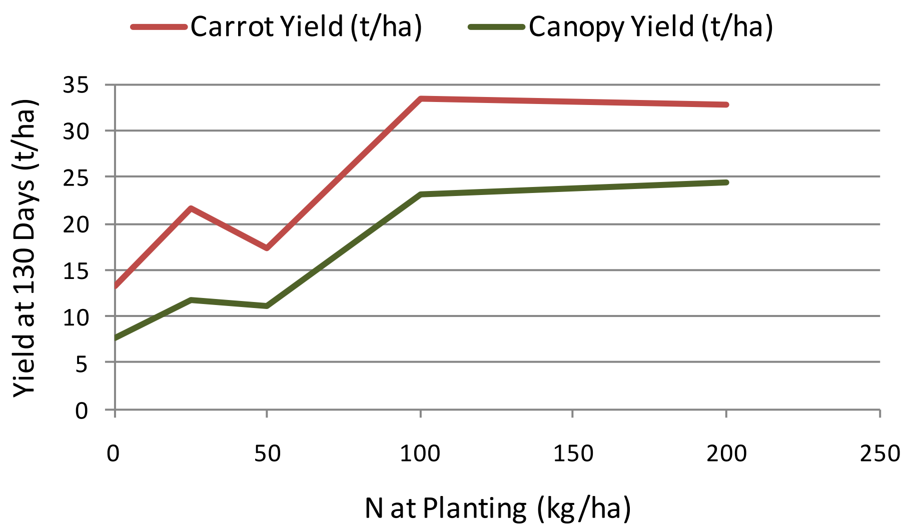


Figure 5.7. *BC0703:* ***Planting 2*** *- Relationship between Carrot & Canopy Yields (t/ha) & N Applied (kg/ha)*

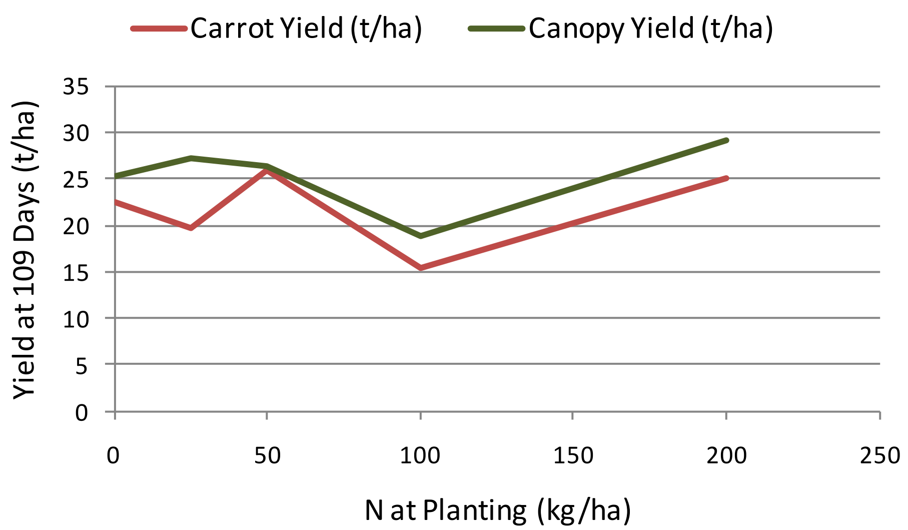


Figure 5.8. *BC0703:* ***Planting 1*** *- Relationship between Canopy & Carrot Yields (t/ha)*

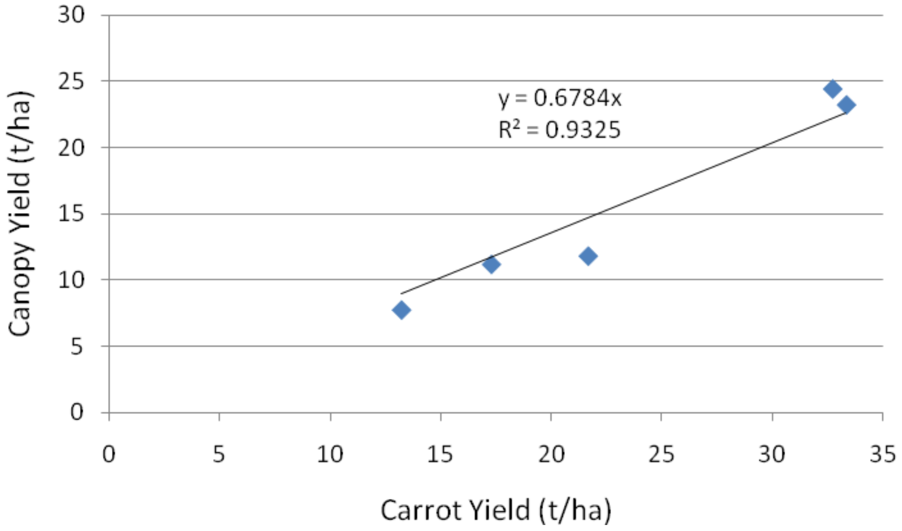


Figure 5.9. *BC0703:* ***Planting 2*** *- Relationship between Canopy & Carrot Yields (t/ha)*

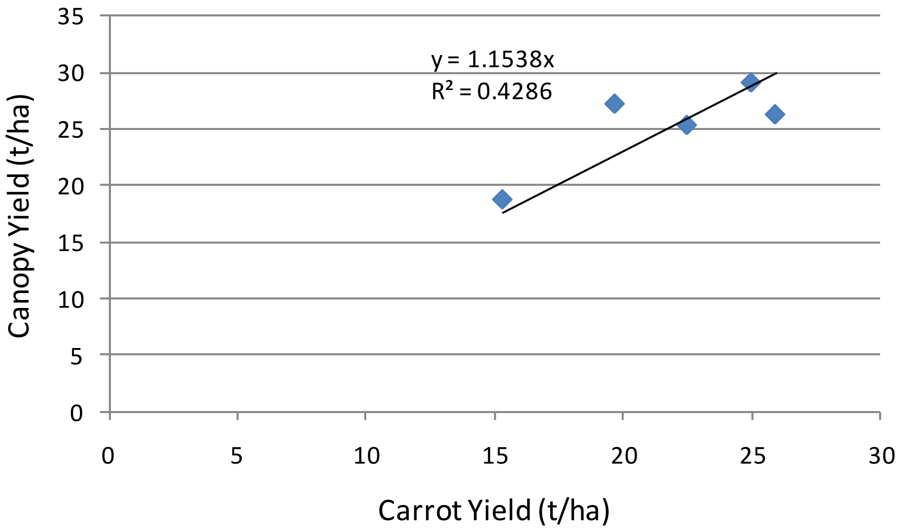


Figure 5.10. *BC0703:* ***Planting 1*** *- Relationship between Brix (°Br) & N Applied (kg/ha)*

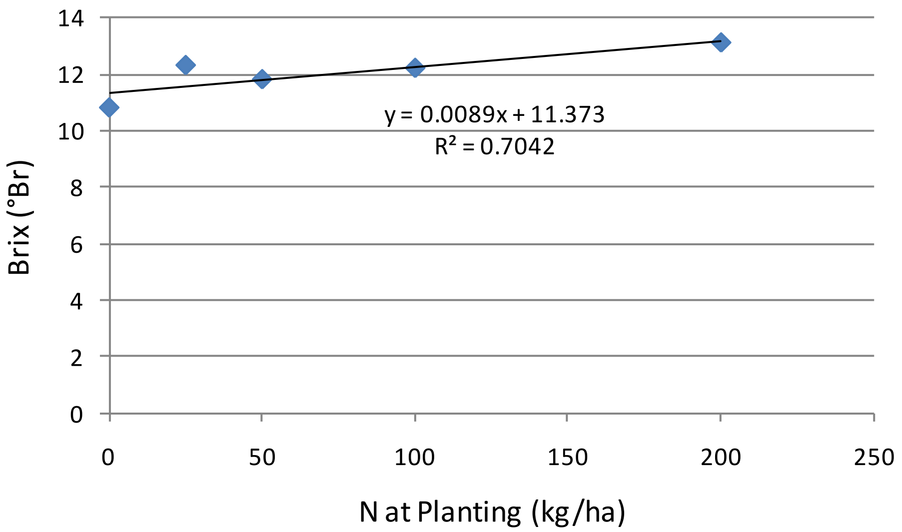


Figure 5.11. *BC0703:* ***Planting 2*** *- Relationship between Brix (°Br) & N Applied (kg/ha)*

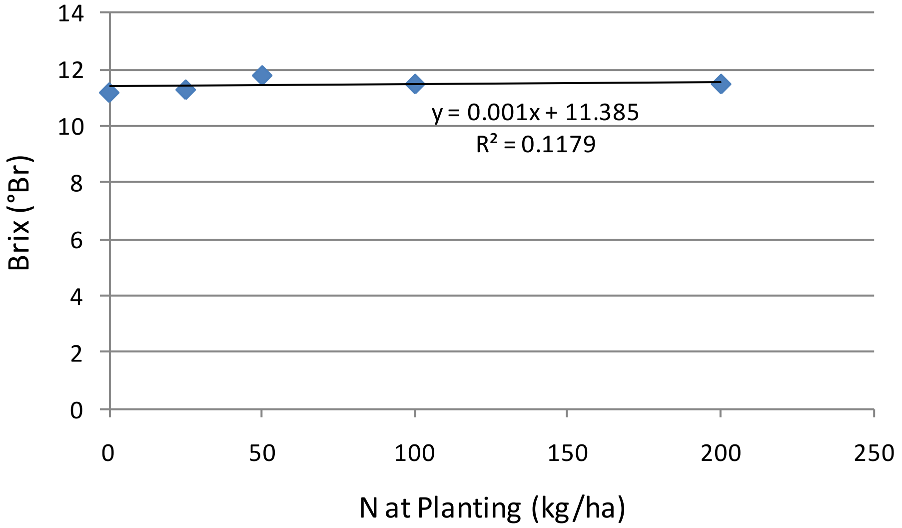


Figure 5.10. *BC0703:* ***Planting 1*** *- Relationship between Anthocyanins (mg%@8.0°Br) & N Applied (kg/ha)*

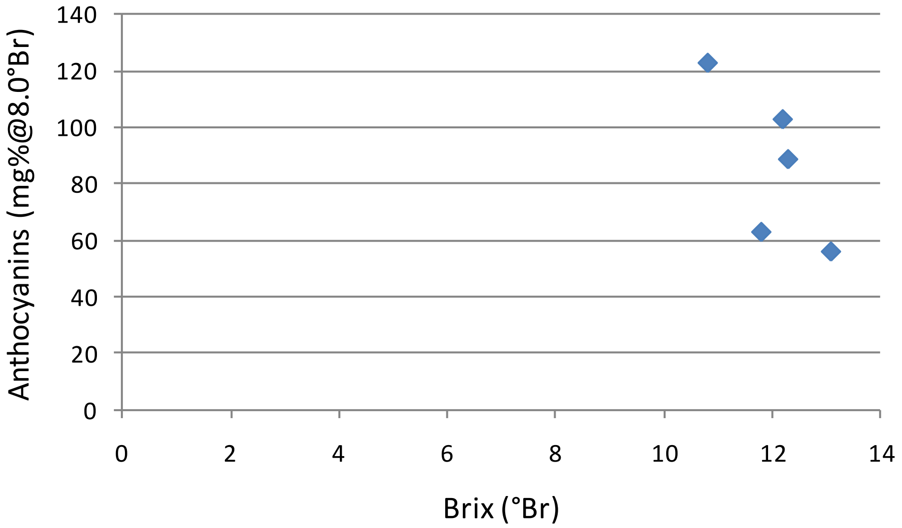


Figure 5.10. *BC0703:* ***Planting 2*** *- Relationship between Anthocyanins (mg%@8.0°Br) & N Applied (kg/ha)*

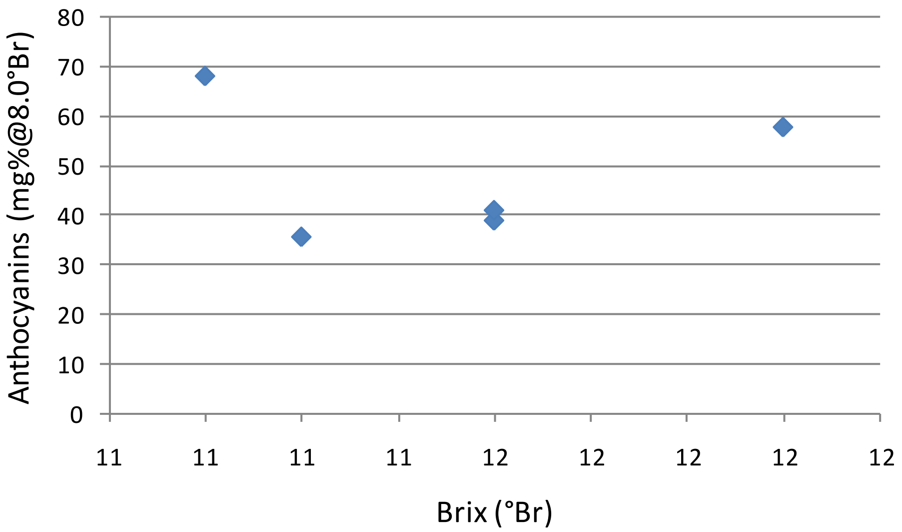


Table 5.25. *BC0703:* ***Planting 1*** *- Foliar Nutrient Levels from Complete Dry-ash Analyses* ***6 Weeks*** *After Planting, classified by N applied*

Treatment (kg N/ha)	N %	P %	K %	S %	Ca %	Mg %	Na %	Cu mg/kg	Zn mg/kg	Mn mg/kg	Fe mg/kg	B mg/kg	Mo mg/kg
0	2.49	0.32	3.52	0.49	2.96	0.37	0.048	4	15	66	69	38	3.7
25	2.90	0.32	3.84	0.55	2.73	0.37	0.034	5	15	60	75	30	1.9
50	2.89	0.37	3.91	0.60	2.66	0.39	0.038	6	16	67	75	30	2.2
100	3.14	0.38	4.44	0.59	2.37	0.34	0.031	6	19	77	61	26	2.1
200	3.37	0.37	4.42	0.53	2.46	0.42	0.056	5	15	79	76	29	1.7
Guide	**2.00**	**0.20**	**2.50**	**0.20**	**1.40**	**0.20**	**<0.5**	**5**	**25**	**30**	**50**	**30**	**0.5**
Average	2.96	0.35	4.03	0.55	2.64	0.38	0.041	5	16	70	71	31	2.3
	High		Normal		Slightly Low			Low					

Table 5.26. *BC0703:* ***Planting 1*** *- Foliar Nutrient Levels from Complete Dry-ash Analyses* ***12 Weeks*** *After Planting, classified by N applied*

Treatment (kg N/ha)	N %	P %	K %	S %	Ca %	Mg %	Na %	Cu mg/kg	Zn mg/kg	Mn mg/kg	Fe mg/kg	B mg/kg	Mo mg/kg
0	2.16	0.30	4.32	0.50	3.22	0.43	0.066	5	15	94	228	37	4.4
25	1.74	0.22	3.85	0.63	3.27	0.48	0.089	4	10	103	98	38	3.6
50	2.36	0.31	3.68	0.62	3.48	0.39	0.025	5	21	139	221	44	5.1
100	1.76	0.22	3.86	0.53	2.80	0.33	0.110	4	11	78	68	37	2.6
200	1.85	0.23	4.77	0.67	3.08	0.47	0.091	4	9	96	84	37	3.1
Guide	**2.00**	**0.20**	**2.50**	**0.20**	**1.40**	**0.20**	**<0.5**	**5**	**25**	**30**	**50**	**30**	**0.5**
Average	1.97	0.26	4.10	0.59	3.17	0.42	0.076	4	13	102	140	39	3.8
	High		Normal		Slightly Low			Low					

Table 5.27. *BC0703:* ***Planting 2*** *- Foliar Nutrient Levels from Complete Dry-ash Analyses* ***6 Weeks*** *After Planting, classified by N applied*

Treatment (kg N/ha)	N %	P %	K %	S %	Ca %	Mg %	Na %	Cu mg/kg	Zn mg/kg	Mn mg/kg	Fe mg/kg	B mg/kg	Mo mg/kg
0	3.74	0.46	4.79	0.77	3.16	0.41	0.037	7	20	100	95	33	3.4
25	3.57	0.49	4.44	0.86	3.02	0.40	0.035	7	20	117	142	34	4.1
50	4.53	0.51	4.89	0.66	2.75	0.49	0.029	8	20	99	207	30	2.4
100	3.09	0.53	4.38	0.88	3.15	0.35	0.039	7	24	94	126	40	6.2
200	4.44	0.54	5.38	0.63	2.66	0.45	0.049	8	23	104	135	26	2.2
Guide	**2.00**	**0.20**	**2.50**	**0.20**	**1.40**	**0.20**	**<0.5**	**5**	**25**	**30**	**50**	**30**	**0.5**
Average	3.87	0.51	4.78	0.76	2.95	0.42	0.038	7	21	103	141	33	3.7
	High		Normal		Slightly Low			Low					

Table 5.28. *BC0703:* ***Planting 2*** *- Foliar Nutrient Levels from Complete Dry-ash Analyses* ***12 Weeks*** *After Planting, classified by N applied*

Treatment (kg N/ha)	N %	P %	K %	S %	Ca %	Mg %	Na %	Cu mg/kg	Zn mg/kg	Mn mg/kg	Fe mg/kg	B mg/kg	Mo mg/kg
0	2.59	0.32	4.12	0.58	3.54	0.39	0.056	7	16	144	88	39	6.0
25	2.86	0.36	4.71	0.95	3.52	0.53	0.040	7	13	116	99	34	2.5
50	2.44	0.38	4.69	0.66	3.09	0.40	0.059	6	14	118	83	34	4.5
100	2.62	0.30	4.17	0.55	3.04	0.36	0.055	6	22	129	83	32	4.0
200	3.30	0.32	3.62	0.88	4.20	0.54	0.097	8	19	121	91	34	4.5
Guide	**2.00**	**0.20**	**2.50**	**0.20**	**1.40**	**0.20**	**<0.5**	**5**	**25**	**30**	**50**	**30**	**0.5**
Average	2.76	0.34	4.26	0.72	3.48	0.44	0.061	7	17	126	89	35	4.3
	High		Normal		Slightly Low			Low					

Discussion (BC0703 – Katherine, NT, 2007)

While some trends appeared in the first planting, they were not supported by similar trends in the second planting.

Pre-trial Soil Nutrient Levels (Table 5.2)
All four samples showed available soil N to be less than 2 ppm with an average requirement 115kg N/ha. P, Fe, Mn, Zn & B were also found to be deficient.

Total Yields

Response to N Applied
Carrot and canopy yields increased as N rates increased in Planting 1 but not in Planting 2 (Tables 5.21 & 5.23, Figures 5.6 & 5.7).

Canopy & Carrot Yield Relationships
Carrot and canopy weights were directly proportional at both plantings (Figures 5.6 & 5.7). High carrot yields also required high canopy weights.

Carrot yields exceeded canopy yields in Planting 1, where the crop was more mature. Canopy yields exceeded carrot yields in Planting 2 where the carrots were still rapidly developing. This was also largely due to the greater variability in carrot tops within individual treatments inside Planting 1.

The Canopy/Carrot yield ratio (Tables 5.21 & 5.23, Figures 5.8 & 5.9) increased slightly at progressively higher rates of N in Planting 1 ($R^2 = 0.93$) but not in Planting 2 ($R^2 = 0.43$).

Carrot Size
Carrot weights were not related to N rates applied in either planting (Tables 5.21 & 5.23). The densities were sufficiently homogeneous (Tables 5.22 & 5.24) as to have no effect on average carrot weights. The 21 day greater maturity of Planting 1 gave a 5g greater average carrot weight.

Brix
Brix was weakly correlated to N applied in Planting 1 (Table 5.22 & Figure 5.10) but not in Planting 2 (Table 5.24 & Figure 5.11). Average Brix levels were good by commercial standards. Plant maturity was a more important factor with higher Brix readings in the more mature planting.

Absorbance & Anthocyanin Content
Anthocyanin levels detected were not related to the rate of N applied.

Brix & Anthocyanin levels bore no clear relationship to each other (Figures 5.9 & 5.10).

Bolting & Forking
Bolting was not seen at all and the frequency of carrot deformities like forking was so low as to preclude any meaningful evaluations.

Foliar Nutrient Levels (Tables 5.25-5.28)

With the exception of N itself, canopy leaf samples taken from the same planting and sample date, showed similar levels of all other key nutrients analysed, regardless of N applied.

Nitrogen
Foliar N levels were well correlated with applied N in Planting 1 at 6 weeks. This was not the case though in Planting 1 by 12 weeks or at all in Planting 2. N levels were highest at 6 weeks in both Plantings, declining by 12 weeks. Marginal deficiencies were detected in 25 & 100kg N/ha samples from Planting 1 but deficiencies were never detected in any of the 0 kg N/ha samples.

As with BC0801, this shows the strong ability of black carrots to scavenge adequate N, even in the apparent absence of adequate soil N (Table 5.20).

Phosphorus
P showed evidence that it may be better absorbed in the presence of higher N rates at 6 weeks but not at 12 weeks. Levels declined slightly between 6 and 12 weeks from normal-high levels to normal levels for both plantings.

As with BC0801, black carrots show a strong capacity to extract sufficient P for normal growth even when indicted soil levels are low (Table 5.20).

Potassium
Foliar K levels were steady from 6 to 12 weeks, with adequate-high levels in all samples.

Calcium
Ca levels were adequate to high in all samples, showing increasing foliar levels from 6 to 12 weeks.

Magnesium
Mg levels were adequate in all samples, showing slightly increasing foliar levels from 6 to 12 weeks.

Sulfur
Levels of foliar S were high and stable from 6 to 12 weeks.

Boron
B was found to be deficient in pre-trial soil testing (Table 5.20). Foliar testing showed marginal-adequate levels at 6 weeks increasing to adequate in all 12 week samples.

Copper
Cu levels were adequate to high and stable from 6 to 12 weeks.

Iron
Fe was found to be deficient in pre-trial soil tests (Table 5.20). However, good Fe levels were detected in all foliar samples, although there was considerable variability between samples and an increasing trend in Planting 1 compared with a decreasing concentration between weeks 6 and 12 in Planting 2.

Manganese
Mn was found to be deficient in pre-trial soil tests (Table 5.20). However, good-high levels were detected in all foliar samples, with levels showing an increasing trend from 6 weeks to 12 weeks.

Molybdenum
All foliar levels of Mo were high with increasing concentrations from 6 to 12 weeks.

Zinc
This was the most defiicient nutrient evaluated in the trial. Zn was found to be deficient in pre-trial soil tests (Table 5.20). Foliar levels were slightly low at 6 weeks, decreasing to very low by 12 weeks.

Sodium
Foliar levels were well inside (below) the safe limit, although foliar levels did increase from 6 to 12 weeks.

Additional Data

BC0901 – Clyde, Vic, 2009

The main presentation of results and materials and methods used for this trial appear in Section 9.1 of this report. However, the foliar and carrot concentrations of nutrients in black carrots compared with Red Hot were determined from pre-harvest foliar (152 days after planting) and harvest samples (taken 176 days after planting).

While plants were still actively growing, the concentration of nutrients in black carrot foliage was consistently lower than in Red Hot leaves (Table 5.29). This was consistent with findings in other project studies, where **larger canopies of similar ages showed greater nutrient dilution**. This was the case, whether comparing larger and smaller canopied LX3632 plants or LX3632 canopies which are always larger, with smaller Red Hot canopies.

In this study (Tables 5.30 & 5.31), LX3632 & Red Hot typically used similar amounts of nutrients/ha when grown under similar conditions. The canopy represented about 40-42% of total crop weight in black carrots (LX3632) but only about 22% of the total crop weight in Red Hot. As most nutrients were found in higher concentrations in the leaves than in the carrots, LX3632 takes up considerably more of most nutrients than Red Hot per tonne of total plant weight and even more per tonne of carrot yield. Total yields of LX3632 were only about 57% of Red Hot under similar conditions.

Table 5.29. *BC0901: Foliar Nutrient Levels from Complete Dry-ash Analyses of Black (LX3632) & Red Hot Carrots, 152 Days After Planting*

Treatment	Nitrate (ppm)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Mo (ppm)	Zn (ppm)	Na (%)	Cl (%)
LX3632	2664	2.95	0.40	5.10	0.45	0.13	0.22	24	3.0	32	18	0.28	29	0.71	2.14
Red Hot	966	2.77	0.44	4.64	0.82	0.19	0.24	24	4.0	44	30	0.60	30	0.95	2.03
Guide		**2.00**	**0.20**	**2.50**	**1.40**	**0.20**	**0.20**	**30**	**5.0**	**50**	**30**	**0.50**	**25**	**<0.5**	**<1.0**
		High		Normal			Slightly Low			Low					

Table 5.30. *BC0901: Estimated Nutrient Removal by a 34.5 t/ha* ***LX3632*** *black carrot crop (using the average yield from all LX3632 treatments as a reference).*

Analysis	Carrots (Dry Ash)	Carrots (% of Fresh Weight)	Leaves (Dry Ash)	Leaves (% of Fresh Weight)	kg/ha used by 34447kg /ha carrots	kg/ha used by 23075kg /ha canopy	Total Crop Use (kg/ha)	Crop Use/tonne of Total Plant Yield (kg)	Crop Use/tonne of Total Carrot Yield (kg)
Cl (%)	0.88	0.106480	3.01	0.301000	36.679	69.456	106.134916	1.845	**3.081**
Na (%)	0.700	0.084700	0.900	0.090000	29.177	20.768	49.944109	0.868	**1.450**
Fe (ppm)	47.0	0.000569	245	0.002450	0.196	0.565	0.761238	0.013	**0.022**
Cu (ppm)	5.0	0.000061	10.9	0.000109	0.021	0.025	0.045992	0.001	**0.001**
B (ppm)	26	0.000312	33	0.000330	0.107	0.076	0.183476	0.003	**0.005**
Zn (ppm)	42	0.000508	74	0.000740	0.175	0.171	0.345815	0.006	**0.010**
Mn (ppm)	13	0.000157	74	0.000740	0.054	0.171	0.224940	0.004	**0.007**
S (%)	0.17	0.020570	0.30	0.030000	7.086	6.923	14.008248	0.244	**0.407**
Mg (%)	0.19	0.022990	0.22	0.022000	7.919	5.077	12.995865	0.226	**0.377**
Ca (%)	0.37	0.044770	1.03	0.103000	15.422	23.767	39.189172	0.681	**1.138**
K (%)	3.10	0.375100	4.80	0.480000	129.211	110.760	239.970697	4.172	**6.966**
P (%)	0.37	0.045073	0.39	0.039000	15.526	8.999	24.525374	0.426	**0.712**
NO_3-N (ppm)	2106	0.025483	3565	0.035650	8.778	8.226	17.004229	0.296	**0.494**
Mo (ppm)	0.30	0.000004	1.46	0.000015	0.001	0.003	0.004619	0.000	**0.000**
N (%)	2.67	0.323070	3.54	0.354000	111.288	81.686	192.973423	3.355	**5.602**
Note: Carrots are 87.9% moisture & Leaves are assumed to be 90% moisture									

Table 5.31. *BC0901: Estimated Nutrient Removal by a 60.1 t/ha* ***Red Hot*** *carrot crop.*

Analysis	Carrots (Dry Ash)	Carrots (% of Fresh Weight)	Leaves (Dry Ash)	Leaves (% of Fresh Weight)	kg/ha used by 60148kg /ha carrots	kg/ha used by 16856kg /ha canopy	Total Crop Use (kg/ha)	Crop Use/tonne of Total Plant Yield (kg)	Crop Use/tonne of Total Carrot Yield (kg)
Cl (%)	0.77	0.093170	2.82	0.282000	56.040	47.534	103.573812	1.345	**1.722**
Na (%)	0.670	0.081070	1.250	0.125000	48.762	21.070	69.831984	0.907	**1.161**
Fe (ppm)	16.0	0.000194	559	0.005590	0.116	0.942	1.058697	0.014	**0.018**
Cu (ppm)	2.8	0.000034	15.3	0.000153	0.020	0.026	0.046168	0.001	**0.001**
B (ppm)	14	0.000169	31	0.000310	0.102	0.052	0.154144	0.002	**0.003**
Zn (ppm)	23	0.000278	81	0.000810	0.167	0.137	0.303925	0.004	**0.005**
Mn (ppm)	7	0.000085	117	0.001170	0.051	0.197	0.248161	0.003	**0.004**
S (%)	0.13	0.015730	0.34	0.034000	9.461	5.731	15.192320	0.197	**0.253**
Mg (%)	0.10	0.012100	0.33	0.033000	7.278	5.562	12.840388	0.167	**0.213**
Ca (%)	0.23	0.027830	1.80	0.180000	16.739	30.341	47.079988	0.611	**0.783**
K (%)	2.87	0.347270	3.16	0.316000	208.876	53.265	262.140920	3.404	**4.358**
P (%)	0.30	0.036300	0.30	0.030000	21.834	5.057	26.890524	0.349	**0.447**
NO_3-N (ppm)	376	0.004550	737	0.007370	2.736	1.242	3.978781	0.052	**0.066**
Mo (ppm)	0.13	0.000002	3.26	0.000033	0.001	0.005	0.006441	0.000	**0.000**
N (%)	1.26	0.152460	2.88	0.288000	91.702	48.545	140.246921	1.821	**2.332**
Note: Carrots are 87.9% moisture & Leaves are assumed to be 90% moisture									

BC0902 – Dareton, NSW, 2009

The main presentation of results and materials and methods used for this trial appear in Section 10 of this report. However, the foliar and carrot concentrations of nutrients in black carrots compared with Red Hot were determined from foliar samples (120 days after planting) and harvest samples (taken 171 days after planting).

As in BC0901, the concentration of nutrients in black carrot foliage was consistent with findings in other project studies, where **larger canopies of similar ages showed greater nutrient dilution** (Table 5.32). This was the case, whether comparing larger and smaller canopied plants of the same variety or large canopies from both varieties or small canopies from both varieties.

In this study (Tables 5.33 & 5.34), LX3632 used slightly higher amounts of nutrients/ha when grown under similar conditions. The canopy represented about 28% of total crop weight in black carrots (LX3632) but only about 16% of the total crop weight in Red Hot. As most nutrients were found in higher concentrations in the leaves than in the carrots, LX3632 takes up considerably more of most nutrients than Red Hot per tonne of total plant weight and even more per tonne of carrot yield. Total carrot yields of LX3632 were very similar to those of Red Hot under similar conditions.

Table 5.32. *BC0901: Foliar Nutrient Levels from Complete Dry-ash Analyses of Larger & Smaller Black (LX3632) & Red Hot Carrots, 120 Days After Planting*

Sample Description	Nitrate (ppm)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Mo (ppm)	Zn (ppm)	Na (%)	Cl (%)
LX3632 (smallest)	1	2.04	0.34	3.74	1.60	0.20	0.35	46	3.7	100	46	1.00	21	0.16	2.85
LX3632 (largest)	151	1.82	0.31	3.61	0.89	0.14	0.20	40	3.1	82	25	0.46	18	0.14	1.36
Red Hot (smallest)	1	2.08	0.37	3.93	2.29	0.26	0.27	43	4.8	167	58	1.02	18	0.27	2.98
Red Hot (largest)	91	2.28	0.28	3.36	1.17	0.17	0.21	30	4.0	90	30	0.44	15	0.15	2.25
Guide		**2.00**	**0.20**	**2.50**	**1.40**	**0.20**	**0.20**	**30**	**5.0**	**50**	**30**	**0.50**	**25**	**<0.5**	**<1.0**
		High		Normal			Slightly Low			Low					

Table 5.33. *BC0902: Estimated Nutrient Removal by a 47.7 t/ha* ***LX3632*** *black carrot crop (using the average yield from all LX3632 treatments as a reference).*

Analysis	Carrots (Dry Ash)	Carrots (% of Fresh Weight)	Leaves (Dry Ash)	Leaves (% of Fresh Weight)	kg/ha used by 47666kg /ha carrots	kg/ha used by 18722kg /ha canopy	Total Crop Use (kg/ha)	Crop Use/tonne of Total Plant Yield (kg)	Crop Use/tonne of Total Carrot Yield (kg)
Cl (%)	0.86	0.104060	2.67	0.267000	49.601	49.988	99.588980	1.731	**2.891**
Na (%)	0.120	0.014520	0.190	0.019000	6.921	3.557	10.478283	0.182	**0.304**
Fe (ppm)	51.0	0.000617	228	0.002280	0.294	0.427	0.721008	0.013	**0.021**
Cu (ppm)	2.5	0.000030	4.3	0.000043	0.014	0.008	0.022469	0.000	**0.001**
B (ppm)	23	0.000278	50	0.000500	0.133	0.094	0.226264	0.004	**0.007**
Zn (ppm)	18	0.000218	30	0.000300	0.104	0.056	0.159983	0.003	**0.005**
Mn (ppm)	13	0.000157	61	0.000610	0.075	0.114	0.189183	0.003	**0.005**
S (%)	0.10	0.012100	0.41	0.041000	5.768	7.676	13.443606	0.234	**0.390**
Mg (%)	0.11	0.013310	0.24	0.024000	6.344	4.493	10.837625	0.188	**0.315**
Ca (%)	0.31	0.037510	2.54	0.254000	17.880	47.554	65.433397	1.138	**1.900**
K (%)	2.86	0.346060	4.20	0.420000	164.953	78.632	243.585360	4.235	**7.071**
P (%)	0.27	0.032670	0.29	0.029000	15.572	5.429	21.001862	0.365	**0.610**
NO_3-N (ppm)	1	0.000012	1	0.000010	0.006	0.002	0.007640	0.000	**0.000**
Mo (ppm)	0.19	0.000002	3.36	0.000034	0.001	0.006	0.007386	0.000	**0.000**
N (%)	0.70	0.084700	1.53	0.153000	40.373	28.645	69.017762	1.200	**2.004**
Note: Carrots are 87.9% moisture & Leaves are assumed to be 90% moisture									

Table 5.34. *BC0902: Estimated Nutrient Removal by a 46.9 t/ha* ***Red Hot*** *carrot crop (using the average yield from all Red Hot treatments as a reference).*

Analysis	Carrots (Dry Ash)	Carrots (% of Fresh Weight)	Leaves (Dry Ash)	Leaves (% of Fresh Weight)	kg/ha used by 46911kg /ha carrots	kg/ha used by 8764kg/ ha canopy	Total Crop Use (kg/ha)	Crop Use/tonne of Total Plant Yield (kg)	Crop Use/tonne of Total Carrot Yield (kg)
Cl (%)	0.66	0.079860	3.53	0.353000	37.463	30.937	68.400045	0.888	**1.137**
Na (%)	0.120	0.014520	0.420	0.042000	6.811	3.681	10.492357	0.136	**0.174**
Fe (ppm)	36.0	0.000436	237	0.002370	0.204	0.208	0.412051	0.005	**0.007**
Cu (ppm)	1.9	0.000023	4.0	0.000040	0.011	0.004	0.014290	0.000	**0.000**
B (ppm)	18	0.000218	37	0.000370	0.102	0.032	0.134599	0.002	**0.002**
Zn (ppm)	11	0.000133	19	0.000190	0.062	0.017	0.079090	0.001	**0.001**
Mn (ppm)	7	0.000085	56	0.000560	0.040	0.049	0.088812	0.001	**0.001**
S (%)	0.09	0.010890	0.37	0.037000	5.109	3.243	8.351288	0.108	**0.139**
Mg (%)	0.09	0.010890	0.29	0.029000	5.109	2.542	7.650168	0.099	**0.127**
Ca (%)	0.27	0.032670	3.54	0.354000	15.326	31.025	46.350384	0.602	**0.771**
K (%)	3.07	0.371470	3.56	0.356000	174.260	31.200	205.460132	2.668	**3.416**
P (%)	0.25	0.030250	0.30	0.030000	14.191	2.629	16.819778	0.218	**0.280**
NO_3-N (ppm)	3	0.000036	1	0.000010	0.017	0.001	0.017905	0.000	**0.000**
Mo (ppm)	0.06	0.000001	2.36	0.000024	0.000	0.002	0.002409	0.000	**0.000**
N (%)	0.60	0.072600	2.88	0.288000	34.057	25.240	59.297706	0.770	**0.986**
Note: Carrots are 87.9% moisture & Leaves are assumed to be 90% moisture									

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6 Canopy Manipulation using Chemical Plant Growth Regulators

Introduction

A variety of prospective tools are available for attempting to manipulate plant canopy vigour. The main lines of enquiry used in these trials were through nutrition, crop density and irrigation manipulation. Another avenue explored was the use of chemical plant growth regulators. This is less desirable because of the lack of any products currently registered for this use in carrots in Australia and the complexity and expense in pursuing this if suitable products are identified. In the event that other methods of reducing crop vigour were ineffective but a reduction in canopy vigour was still found to be desirable, some research identifying any products that showed some technical benefits was briefly investigated in two pilot studies.

Products which principally interfere with gibberellic acid synthesis or activity were identified as being the most widely available and likely to show a result, based on their use in other crops. These products inhibit or retard cell elongation and have the effect of producing plants with a shortened and often thickened growth habit.

A preliminary study was undertaken at Bowen, Qld using paclobutrazol only. This was followed up with a study at Dareton, NSW using several other candidate products.

Paclobutrazol is chemically related to the triazole fungicides. It reduces internode lengths of new shoots and causes earlier formation of terminal buds. However, it has been used in Australia for example to reduce vegetative growth in mango, stone fruit and apple trees for example (Payback® product label, Dec 2004). A product containing the triazoles fungicides cyproconazole and propiconazole was also evaluated at high use rates to see whether a similar growth regulatory effect could be achieved in conjunction with any added benefits that might flow from disease control. Trinexapac-ethyl, another growth regulator used mainly for reducing stem growth in grasses but with some potential dicotyledon activity at much higher rates was also evaluated.

While the key measurements relate to the actual and relative yields of carrots and canopy, growth regulators may have other effects such as altering the onset of bolting, the amount of soluble solids (Brix) or concentration of anthocyanins.

Key Outcomes

- For reducing canopy volume, black carrots are most responsive to plant growth regulator products in early development (6 weeks after planting) and less responsive as plants mature (12 weeks or later).

- Paclobutrazol (Payback®) was highly effective at reducing canopy growth when applied 6 weeks after planting. However, there is evidence that at 1250g ai (active ingredient)/ha paclobutrazol also reduces carrot weights and yields. This rate proved excessive and further, more detailed evaluation would be required to develop a suitable program for use rates and application timing(s). Nonetheless it does prove canopy volume can be manipulated with at least one growth regulator product.

- Trinexapac-ethyl (Moddus®) and propiconazole + cyproconazole (Tilt® Xtra) were ineffective for reducing canopy volume, even at significantly higher rates than typically used in other crops.

  <u>NB</u>: None of the above products are currently registered for use in carrots in Australia.

Materials & Methods (BC0702 – Bowen, Qld, 2007)

This was trial was also used to determine the suitability of the location for black carrot production but allowed a preliminary evaluation of paclobutrazol to be made at mid and late stages of crop development based on three different plant ages.

Location
This trial was located near Bowen, at the QDPI Research Station (approx: 20° 00′ 42″ S, 148° 12′ 51″ E) inside a dedicated trial area specially worked for the purpose and a grey-black clay loam typical of the region.

Design
Single beds, each 30m long were planted with seed tape on three separate dates. Plots consisted of two pair-planted rows (4 single rows in total) on a single bed 1.6 m wide (bed centre to adjacent bed centre). Treatment plots were each 3.75m long, providing 2 replications per planting date for each of 4 different treatments.

Soil testing prior to planting showed ideal nutrient status for carrots with no deficiencies.

Beds were unformed but soil was prepared several days before planting. All seed was planted to a depth of about 5-10 mm using seed tape. Exposed tape was lightly covered by hand.

No thinning was conducted. Emergence was somewhat uneven due to varied seed viability.

Irrigation was provided by drip-lines – One between each pair of rows. Irrigation intervals were determined by the cooperator and scheduled as for the rest of the farm, typically a single application of 6-9 mm/day once a day.

Planting Dates were 02 May 2007, 25 May 2007 & 17 Jul 2007. Heavy rain and waterlogging prevented planting in June.

No fungicides or herbicides were applied and all weeding was done by hand. Treatments were applied 11 Sep 2007 using a motorized hand-held boom spray applying treatments in a total volume of 250L/ha.

Table 6.1 *– BC0702: Treatment Details*

Treatment	Rate of Payback® (mL/ha)	Rate of paclobutrazol (gai/ha)	Crop Age (Days After Planting Crops 1-3 respectively)
1	Untreated	**-**	132, 109 & 56
2	250	**63**	132, 109 & 56
3	1000	**250**	132, 109 & 56
4	5000	**1250**	132, 109 & 56

Evaluation
Photographs were taken at various stages between emergence and harvest. Plots from the third planting only were harvested 124 days after planting, on 18 Nov 2007 (200, 177 days after plantings 1 & 2 which were too mature for harvest). Due to the uneven plant numbers in stands, harvesting figures were generated from a 50 plant sample in each plot (composite sample from both replicates). After taking photographs of whole samples, canopy and carrot weights were measured. Plot samples were packed in plastic bags and sent by overnight road transport to SDS Beverages in Merbein. Here they were cool stored for a several weeks at 4° C, before being juiced. A 500 mL sample of juice was kept from each sample, frozen and subsequently analysed in SDS's Merbein laboratory for Brix using a refractometer and anthocyanin content using an absorbance spectrophotometer.

Results (BC0702 – Bowen, Qld, 2007)

Table 6.2. *BC0702: Carrot & Canopy Weights – Planting 3 (kg/50 plants), classified by paclobutrazol Rate (gai/ha)*

Payback® Rate (mL/ha)	50 Carrot Weight (kg)	Payback® Rate (mL/ha)	50 Canopy Weight (kg)
1000	7.76	**Untreated**	9.78
5000	7.16	**1000**	9.71
Untreated	7.02	**250**	9.08
250	6.74	**5000**	8.84

Table 6.3. *BC0702: Average Carrot & Canopy Weights & Canopy/Carrot Weight Ratio – Planting 3 (kg/50 plants), classified by paclobutrazol Rate (gai/ha)*

Payback® Rate (mL/ha)	Average Carrot Weight (g)	Payback® Rate (mL/ha)	Average Canopy Weight (g)	Payback® Rate (mL/ha)	Canopy/ Carrot Ratio
1000	155	**Untreated**	196	**Untreated**	1.39
5000	143	**1000**	194	**250**	1.35
Untreated	140	**250**	182	**1000**	1.25
250	135	**5000**	177	**5000**	1.23

Table 6.4. *BC0702: Brix (°Br), Absorbance (@538nm) & Anthocyanins (mg%@8.0°Br) – Planting 3 (kg/50 plants), classified by paclobutrazol Rate (gai/ha)*

Payback® Rate (mL/ha)	Brix (°Br)	Payback® Rate (mL/ha)	Absorbance (@538nm)	Payback® Rate (mL/ha)	Anthocyanins (mg%@8.0°Br)
Untreated	10.5	**5000**	1.220	**5000**	125.4
1000	10.3	**250**	1.078	**250**	110.8
250	10.2	**1000**	0.762	**1000**	78.3
5000	10.1	**Untreated**	0.448	**Untreated**	46.0

Discussion (BC0702 – Bowen, Qld, 2007)

It is difficult to make direct yield comparisons with other trials due to the method necessarily employed at harvest. Uneven germination and subsequent plant establishment meant harvesting set lengths of plot would not yield any valid comparisons. This was one of the earliest trials conducted and demonstrated the need for overcoming uneven establishment in small plot trials in order to achieve meaningful comparisons in future work.

The need for a single assessment date meant the selected date would not be ideal for all plantings. Applications made to plantings 1 & 2 appear to have been too late in crop development to be effective. Planting 1 was over-mature irrespective of any treatment effects. However, application at 8 weeks of age (56 days after planting) to planting 1 appears to have had some effect, though far less than anticipated, particularly at the highest rates used.

Planting 1

Treatments did show a steadily declining canopy/carrot weight ratio at increasing rates of paclobutrazol (Table 4.3), although the effect was not strongly rate responsive. The canopy weights, especially in relation to carrot yields are very high compared to other trials. The same was true for average carrot weights. However, this is readily explained by the harvesting method already described.

Treatments did not affect actual canopy or carrot weights. Similarly Brix & Anthocyanin levels were unrelated to paclobutrazol rates applied. Overall Brix levels were commercially acceptable. Anthocyanin levels were highly variable but the two best samples of four taken were excellent, both far exceeding 80mg%.

Bolting

Late bolting had begun in plant 1 but this was entirely related to the age of the crop (200 days). There were the first signs of late bolting in planting 2 which by this time was 177 days old.

Materials & Methods (BC0803 – Dareton, NSW, 2008)

This formed the main study for growth regulator effects and was based on the findings from BC0802. With relatively subtle effects only being seen in the preliminary trial, it was decided to investigate earlier application using a higher rate of paclobutrazol as well as some other potentially effective products.

Location
This trial was located at the NSW DPI Research Station near Dareton, NSW (approx: 34° 05′ 43″ S, 142° 00′ 53″ E, elevation 51 m) inside a dedicated area worked up managed solely for the purpose of conducting the trial, on a red loamy sand, typical of the region.

Design
9 single plot treatments including 3 Untreated reference plots in a single bed. The trial bed consisted of a single pair of rows rather than the two pairs normally used.

Base Nutrition
As this was primarily a nitrogen study, care was taken to avoid applying ANY nitrogen as a base. All nitrogen was applied as urea (see treatment list in Table 5.1 below).

14 Jan 2008: Hifert Single Superphosphate (0:9:0 N:P:K) applied at 500kg/ha (45kg P/ha) and incorporated to 60cm with deep ripper. 15 Jan 2008: Hifert Sulfate of Potash (0:0:41:17 N:P:K:S) applied at 181kg/ha (75kg K/ha) & incorporated to 7cm with disc harrows. Soil testing prior to planting showed good nutrient status for carrots apart from P which remained a little low even after the superphosphate application. Also, marginal trace element levels indicated a need for monitoring and if necessary applying these during crop development.

Marginal and slight trace element deficiencies recorded in foliage at 10 weeks were treated using Richgro Complete Trace Elements, applied at 100kg/ha (10g/m^2) giving the following: S 11.5kg/ha; Fe 12.0kg/ha; Zn 1.1kg/ha; Ca 3.5kg/ha; Cu 0.5kg/ha; Mn 3.1kg/ha; B 0.1kg/ha; Mg 2.0kg/ha; Mo 0.04kg/ha.

Planting
All seed was hand planted on 23 Jan 2008, to a depth of about 5-10 mm using a seed-tape planter with seed spaced at 1 cm intervals. Despite the close plantings, thinning was not necessary due to poor seed viability.

Treatment
Products were applied as foliar sprays using a single flat-fan jet applying 250L water volume/ha on 05 Mar 2008 (6 weeks) & 16 May 2008 (12 weeks).

Irrigation
Irrigation was provided by solid set sprinklers arranged in a square grid pattern with 3.2 metres between risers. Irrigation was applied slightly in excess of requirement to ensure it was not a limiting factor but care was taken to avoid over-watering and leaching of applied nitrogen.

Maintenance
No fungicides were used but the herbicides Linuron® 500 WG + Gesagard® 500 SC were applied at 2.2kg/ha + 2.2L/ha respectively (Single jet, flat-fan knapsack sprayer at 250L/ha output) 21 Feb 2008 several weeks prior to planting.

Table 6.5. *BC0803: Details of Products Evaluated*

Product Name	Active Ingredient	Active Ingredient Loading in formulated Product (g/L)
Payback®	paclobutrazol	250
Moddus®	trinexapac-ethyl	250
Tilt® Xtra	propiconazole cyproconazole	250 80

NB: None of the above products are currently registered for use in carrots in Australia.

Table 6.6. *BC0803: Treatment (plant density) Details*

No.	Application 6 Weeks after Planting	Application 12 Weeks after Planting	Untreated Reference
1	Payback 10L/ha	Untreated	1
2	Untreated	Untreated	**1**
3	Moddus 10L/ha	Untreated	1
4	Tilt Xtra 10L/ha	Untreated	2
5	Untreated	Untreated	**2**
6	Untreated	Payback 1L/ha	2
7	Untreated	Payback 5L/ha	3
8	Untreated	Untreated	**3**
9	Untreated	Payback 10L/ha	3

NB: None of the above products are currently registered for use in carrots in Australia.

Evaluations

Photographs were taken at various stages of crop development. Canopy vigour was visually rated immediately prior to harvest. 1.0m Tops were removed by hand. Carrots were individually sorted into size categories (26+, 21-25 mm & <21 mm) according to the widest point at the shoulders (crown). Branched or otherwise deformed carrots were separated within each of these size groupings from unforked carrots. Each of these categories were weighed and individual carrots in each group counted.

Results (BC0803 – Dareton, NSW, 2008)

Table 6.7. *BC0803: Total & Harvestable Yields (t/ha), classified by Growth Regulator Treatment, Rate & Time Applied*

Treatment	TOTAL Yield - Carrots (t/ha)	Treatment	YIELD 21+ mm - Carrots (t/ha)	Treatment	YIELD 26+ mm - Carrots (t/ha)
PB 10 L (3)	95.250	**PB 10 L (3)**	95.013	**PB 10 L (3)**	94.200
UTC (3)	86.325	**UTC (3)**	85.850	**UTC (3)**	84.750
UTC (2)	68.238	**PB 5 L (3)**	67.938	**PB 5 L (3)**	67.600
PB 5 L (3)	68.150	**UTC (2)**	67.850	**UTC (2)**	67.563
PB 1 L (2)	67.863	**PB 1 L (2)**	67.563	**PB 1 L (2)**	66.525
TX 10 E (2)	50.550	**TX 10 E (2)**	48.763	**TX 10 E (2)**	47.313
MD 10 E (1)	48.788	**MD 10 E (1)**	47.700	**MD 10 E (1)**	46.613
UTC (1)	44.388	**UTC (1)**	42.550	**UTC (1)**	40.763
PB 10 E (1)	28.038	**PB 10 E (1)**	25.600	**PB 10 E (1)**	22.588

Note: PB = Payback; TX = Tilt Xtra; MD = Moddus; UTC = Untreated Control; E = Early (6 week application); L = Late (12 week application); First Number = Product Rate Applied (L/ha); (*) = Untreated reference Plot to compare value with.

Table 6.8. *BC0803: Undersize Yields (t/ha), classified by Growth Regulator Treatment, Rate & Time Applied*

Treatment	Carrot Yield <21mm (t/ha)	Treatment	Carrot Yield 20-25mm (t/ha)
PB 10 E (1)	2.438	**PB 10 E (1)**	3.013
UTC (1)	1.838	**UTC (1)**	1.788
TX 10 E (2)	1.788	**TX 10 E (2)**	1.450
MD 10 E (1)	1.088	**UTC (3)**	1.100
UTC (3)	0.475	**MD 10 E (1)**	1.088
UTC (2)	0.388	**PB 1 L (2)**	1.038
PB 1 L (2)	0.300	**PB 10 L (3)**	0.813
PB 10 L (3)	0.238	**PB 5 L (3)**	0.338
PB 5 L (3)	0.213	**UTC (2)**	0.288

Note: PB = Payback; TX = Tilt Xtra; MD = Moddus; UTC = Untreated Control; E = Early (6 week application); L = Late (12 week application); First Number = Product Rate Applied (L/ha); (*) = Untreated reference Plot to compare value with.

Table 6.9. *BC0803: Average Carrot Weights for Total & Harvestable Yields (g), classified by Growth Regulator Treatment, Rate & Time Applied*

Treatment	Av. Carrot Weight - AllSizes (g)	Treatment	Av. Carrot Weight 21+mm (g)	Treatment	Av. Carrot Weight 26+mm (g)
PB 1 L (2)	217	**PB 1 L (2)**	246	**PB 1 L (2)**	280
UTC (2)	188	**UTC (2)**	217	**UTC (2)**	225
PB 10 L (3)	177	**PB 5 L (3)**	187	**PB 10 L (3)**	204
PB 5 L (3)	176	**PB 10 L (3)**	185	**PB 5 L (3)**	193
UTC (3)	157	**UTC (3)**	172	**UTC (3)**	183
MD 10 E (1)	100	**MD 10 E (1)**	132	**MD 10 E (1)**	149
TX 10 E (2)	90	**TX 10 E (2)**	130	**TX 10 E (2)**	140
UTC (1)	87	**UTC (1)**	122	**UTC (1)**	136
PB 10 E (1)	43	**PB 10 E (1)**	60	**PB 10 E (1)**	70

Note: PB = Payback; TX = Tilt Xtra; MD = Moddus; UTC = Untreated Control; E = Early (6 week application); L = Late (12 week application); First Number = Product Rate Applied (L/ha); (*) = Untreated reference Plot to compare value with.

Table 6.10. *BC0803: Canopy Biomass, Canopy Yields & Canopy/Carrot Weight Ratios, classified by Growth Regulator Treatment, Rate & Time Applied*

Treatment	Relative Canopy Biomass (%)	Treatment	Canopy Yield (t/ha)	Treatment	Canopy/Carrot Weight Ratio
UTC (2)	100	**UTC (3)**	62.500	**UTC (2)**	0.76
UTC (3)	100	**UTC (2)**	52.188	**PB 5 L (3)**	0.74
PB 1 L (2)	90	**PB 5 L (3)**	50.313	**UTC (3)**	0.72
PB 5 L (3)	80	**PB 1 L (2)**	47.813	**PB 1 L (2)**	0.70
PB 10 L (3)	60	**PB 10 L (3)**	41.563	**PB 10 L (3)**	0.44
UTC (1)	50	**UTC (1)**	17.063	**UTC (1)**	0.38
TX 10 E (2)	40	**MD 10 E (1)**	15.938	**MD 10 E (1)**	0.33
MD 10 E (1)	30	**TX 10 E (2)**	15.388	**TX 10 E (2)**	0.30
PB 10 E (1)	5	**PB 10 E (1)**	6.413	**PB 10 E (1)**	0.23

Note: PB = Payback; TX = Tilt Xtra; MD = Moddus; UTC = Untreated Control; E = Early (6 week application); L = Late (12 week application); First Number = Product Rate Applied (L/ha); (*) = Untreated reference Plot to compare value with.

Table 6.11. *BC0803: Average Plant Spacing, classified by Growth Regulator Treatment, Rate & Time Applied*

Treatment	Av. Plant Spacing (mm)	Treatment	% Yield Forked
PB 1 L (2)	64.0	**UTC (3)**	75
UTC (2)	55.2	**PB 5 L (3)**	74
PB 5 L (3)	51.6	**PB 1 L (2)**	71
MD 10 E (1)	41.0	**UTC (1)**	55
UTC (1)	39.0	**PB 10 L (3)**	46
PB 10 L (3)	37.2	**MD 10 E (1)**	45
UTC (3)	36.4	**TX 10 E (2)**	41
TX 10 E (2)	35.6	**UTC (2)**	41
PB 10 E (1)	30.8	**PB 10 E (1)**	26

Note: PB = Payback; TX = Tilt Xtra; MD = Moddus; UTC = Untreated Control; E = Early (6 week application); L = Late (12 week application); First Number = Product Rate Applied (L/ha); (*) = Untreated reference Plot to compare value with.

Table 6.12. *BC0803: Carrot Shapes as a Proportion of Total Straight (Unforked) Yield, classified by Growth Regulator Treatment, Rate & Time Applied*

Treatment	% Short Carrots	Treatment	% Normal Carrots	Treatment	% Long Carrots
UTC (3)	46	**PB 5 L (3)**	89	**UTC (2)**	70
TX 10 E (2)	15	**PB 10 E (1)**	65	**MD 10 E (1)**	58
UTC (1)	14	**PB 1 L (2)**	61	**UTC (1)**	49
PB 5 L (3)	11	**TX 10 E (2)**	52	**PB 10 L (3)**	49
PB 10 E (1)	9	**PB 10 L (3)**	46	**PB 1 L (2)**	33
PB 1 L (2)	6	**MD 10 E (1)**	40	**TX 10 E (2)**	33
PB 10 L (3)	5	**UTC (1)**	37	**UTC (3)**	28
MD 10 E (1)	2	**UTC (2)**	30	**PB 10 E (1)**	26
UTC (2)	0	**UTC (3)**	26	**PB 5 L (3)**	0

Note: PB = Payback; TX = Tilt Xtra; MD = Moddus; UTC = Untreated Control; E = Early (6 week application); L = Late (12 week application); First Number = Product Rate Applied (L/ha); (*) = Untreated reference Plot to compare value with.

Table 6.13. *BC0803: Brix (°Br), Absorbance (@538nm) & Anthocyanins (mg%@8.0°Br), classified by Growth Regulator Treatment, Rate & Time Applied*

Treatment	Brix (°Br)	Treatment	Absorbance (@538nm)	Treatment	Anthocyanins (mg%@8.0°Br)
TX 10 E (2)	13.1	**MD 10 E (1)**	0.902	**MD 10 E (1)**	92.7
PB 10 E (1)	12.5	**UTC (1)**	0.811	**UTC (1)**	83.3
PB 10 L (3)	12.2	**PB 10 E (1)**	0.692	**TX 10 E (2)**	69.3
PB 5 L (3)	11.1	**TX 10 E (2)**	0.674	**PB 10 E (1)**	69.3
UTC (2)	10.8	**PB 10 L (3)**	0.573	**PB 10 L (3)**	58.9
UTC (1)	10.6	**UTC (3)**	0.485	**UTC (3)**	49.8
MD 10 E (1)	10.5	**PB 5 L (3)**	0.317	**PB 5 L (3)**	32.6
PB 1 L (2)	10.4	**PB 1 L (2)**	0.235	**PB 1 L (2)**	24.2
UTC (3)	10.1	**UTC (2)**	0.146	**UTC (2)**	15.0

Note: PB = Payback; TX = Tilt Xtra; MD = Moddus; UTC = Untreated Control; E = Early (6 week application); L = Late (12 week application); First Number = Product Rate Applied (L/ha); (*) = Untreated reference Plot to compare value with.

Photo 6.1*: BC0803 – LX3632 14 days after treatment with Payback 10.0L/ha, applied **6** weeks after planting*

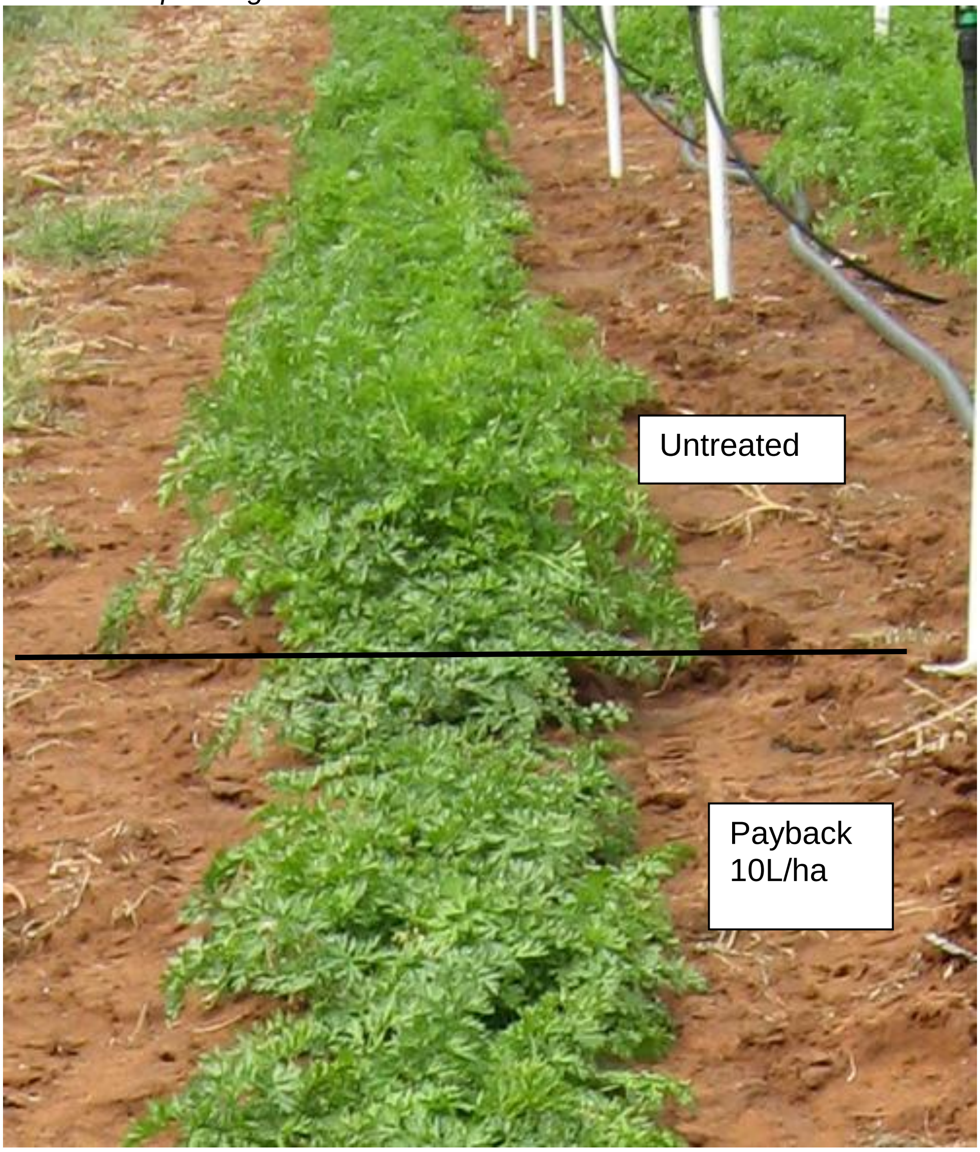


***Photo 6.2**: BC0803 – LX3632 43 days after treatment with Payback 10.0L/ha, applied **6** weeks after planting*

***Photo 6.3**: BC0803 – LX3632 at harvest 120 days after treatment with Payback 10.0L/ha, applied **6** weeks after planting*

***Photo 6.4**: BC0803 – LX3632 at harvest 48 days after treatment with Payback 10.0L/ha, applied **12** weeks after planting. Very subtle effect on canopy only.*

Photo 6.5*: BC0803 – LX3632 at harvest 120 days after treatment with Payback 10.0L/ha, applied* ***6*** *weeks after planting. Note the size & flattening of the canopy*

Photo 6.6*: BC0803 – LX3632 at harvest 48 days after treatment with Payback 10.0L/ha, applied* ***12*** *weeks after planting.*

Discussion (BC0803 – Dareton, NSW, 2008)

The use of "half-beds" (2 rows) in this trial had the effect of increasing both yield and average carrot weights compared with the full beds (2 x 2 rows) used in most other trials, as plants had better access to space and light. For this reason it is more important to look at the relative values for these parameters rather than the actual figures.

As there was a perceptible & progressive decrease in plant size from the eastern end to the western end of the trial, three reference untreated plots were evaluated and the relevant reference for all of the other plots is indicated by the bracketed figure. This is referred to below as the blocking effect.

Canopy Yields (Table 6.10)
Visual assessments just prior to harvest closely matched actual canopy yields. Even allowing for blocking effects, all plots receiving early applications of products showed reduced canopy weights. The rank order for canopy weights was very similar for canopy/carrot weight ratios. **This reinforces findings in a large number of other studies that link higher yields of carrots with higher canopy weights**.

Total and Harvestable Carrot Yields (Table 6.7)
Total yields varied enormously but the blocking effect showed higher yields to the west. The greatly reduced yield in the early application of Payback at 10L/ha compared with the reference treatments, does suggest, however, this rate of paclobutrazol used at this earliest timing reduces yield. This could also be related to the closer average plant spacing found in this treatment. There was no indication that late applications of Payback, even at 10L/ha reduced yields. There was no compelling evidence that Moddus or Tilt Xtra reduced yields. The trends for harvestable yields were virtually identical.

Undersize Yields (Table 6.8)
Again the blocking effect showed higher yields of undersize carrots to the east. Again the yield for the early Payback treatment does indicate 10.0L/ha increased the amount of unharvestable sized material. There was no compelling evidence that Moddus or Tilt Xtra altered undersize carrot yields. This was true whether a 21 or 26mm minimum shoulder width was imposed.

Average Carrot Weights (Table 6.9)
The blocking effect was less pronounced for carrot weights than for yields but the plots with the lowest carrot weights included all of the western plots. Again though, the greatly reduced size of carrots in the early applied Payback treatment, even compared to same block comparators, indicate a real reduction. The low weights for Tilt Xtra are more likely related to average plant spacing than any real treatment effect. Moddus did not reduce average carrot weight. The same observations applied whether total or harvestable carrot weights were compared.

Average Plant Spacing (Table 6.11)
Unlike other subsequent trials which were hand sown at high rates then thinned, the variable seed viability did result in considerable plant spacing variability. Average plant spacings varied from around 31-64mm. There was also a strong relationship between average carrot weight (Table 6.9) and plant spacing (higher average weights at wider spacings). Average plant spacing was not closely related to the blocking effect.

% Carrot Forking (Table 6.11)
Forking in other trials has tended to be more common in larger carrots. The trend was similar in this trial with more forking at wider spacings (where average carrot sizes were also higher).

Carrot Shape (Table 6.12)
Growth regulators could reasonably be expected to have some effect on proportions of particularly long or short carrots. However, there was no indication that any product applied early or late altered proportions of carrot shapes. In fact the three treatments with the lowest proportion of standard proportioned carrots were the three untreated plots.

Brix, Absorbance & Anthocyanin Content (Table 6.13)
Brix levels showed no link to products or timings of applications. There was a weak association between lower yields and higher Brix levels. Levels overall were commercially acceptable but not especially notable.

Anthocyanin levels were extremely variable and unrelated to products used or timings applied, with the three untreated plots spanning the range of results. Levels overall were acceptable but not remarkable.

7 Evaluation of New Anti-oxidant Carrot Varieties

Introduction

During the planning for this project, it was anticipated a range of new varieties were likely to be made available through Excel Fresh. Other candidate seed companies were not actively sought due to commercial arrangements regarding seed supply between Excel Fresh and SDS Beverages. Nonetheless, Excel Fresh seemed likely to have new lines of their own for evaluation as well as potentially access to other licensed lines. However, only a single season study was conducted for two reasons. Firstly the non-availability of newer lines through Excel Fresh after that time and secondly the superiority of LX3632 from the first season's evaluations.

The primary purpose of the variety work was to identify better lines of high anthocyanin carrots, i.e.; higher yielding, lower bolting, less vigorous top growth, higher anthocyanins etc. However, other pigmented varieties have recently become available and become interesting for both the processing and fresh industries. Both red carrots (high in lycopenes) and yellow or white carrots (high in luteins) are seen more widely in markets outside Australia.

In the main trial (BC0706) five processing carrot varieties were evaluated for a broad range of agronomic and post-harvest processing attributes. The primary aim was determine whether any new high anthocyanin varieties showed more desirable characteristics than the current standard LX3632. However, due to lack of very much new material to screen, the scope of the trial was broadened to include one other pigmented variety as well as the high carotene standard Red Hot, to determine any practical similarities or differences in growing and managing them. With the reduced number of varieties included, more in-depth evaluations were undertaken than originally planned.

BC0804 was a supplementary observation trial only, consisting of a series of small unreplicated plots using the same varieties.

Key Outcomes

Excel Fresh variety LX3632 remains the preferred high anthocyanin cultivar for processing. The detailed reasons for this are outlined below:

Yield

Yields were widely separated by variety and complicated by bolting. However, after adjusting yields for bolting the relative performance of varieties remained the same. As there is no prescribed standard for minimum carrot size, carrots under 21 and 26 mm were collected and separated from the "harvestable" yield. However, regardless of whether, a 21 or 26 mm cut-off was imposed, losses were deemed to be well under 1% and insignificant. Total adjusted yield then was a perfectly adequate measure of relative varietal performance. Adjusted carrot yields from highest to lowest were as follows:

- The yellow variety LX256-7 produced nearly 79 tonnes/ha
- Red Hot over 62 tonnes/ha
- The black standard LX3632 nearly 49 tonnes/ha
- LX255-7 (purple) just over 46 tonnes/ha
- LX254-7 (purple) over 37 tonnes/ha.

Another attribute that was observed was the superior ability of the Red Hot and yellow carrots to "fill" any available spaces in rows, sometimes producing a "wall" of carrots with crowns touching. By contrast, carrot size was much more variable in the three high anthocyanin varieties and seemed to reflect the genetic potential of individuals in the population where some individuals did or did not have the capacity to grow into available space.

Growth Rate
The first clear observation in varietal differences was the rate of growth after emergence. The three high anthocyanin varieties showed most rapid early growth, producing canopy biomass at a much faster rate than the yellow and standard carotene varieties.

Bolting
This was soon followed by severe bolting, first assessed 61 DAP, in the high anthocyanin varieties but not in the orange or yellow varieties. Bolting was most severe in the two candidate purple varieties LX254-7 (77%) and LX255-7 (59%). The standard black LX3632 also bolted but to a much lower level (15%). This timing was too early for a commercial crop of black carrots in this area, though it did separate relative varietal susceptibilities very clearly.

Brix
At harvest, Brix for all anthocyanin carrots lay in the 10-11 range – good but not exceptional and not significantly different between varieties. The current standard black LX3632 and the purple variety LX254-7 yielded about three times more anthocyanins than the purple variety LX255-7.

Cracking
Cracking was quite severe in some individual plots but with as much variance within as between varieties, it was not significant by variety overall. However, it appears the ratio of canopy to carrot production in plots strongly influenced the prevalence of cracking. This was mainly attributed differing levels of water uptake according to the very different canopies certain varieties produced.

Forking
Forking and side-shoot production was also quite severe in some instances but highly variable overall and thought to be mainly a function of *Pythium spp*. or some other damping off fungal pathogen attack during the first few weeks of tap-root establishment. Varietal differences were not significant. The black standard LX3632 did show a tendency to produce carrots with swollen fibrous roots around the top third of the crown that was not seen in other varieties. The cause of this is not known but may become clearer in future establishment disease trials.

Fresh Market
The two purple varieties LX244-7 & LX255-7 which failed to show any key benefits for the processing market may still be of interest as fresh market carrots. They had a smoother skin, tended to be a more consistently marketable shape and were generally more visually appealing than LX3632. The same was true for the yellow variety LX256-7 which not only had good visual appeal but also yielded better than Red Hot. SDS Beverages also expressed interest in developing a lutein based product based on the yellow carrot.

Materials & Methods

BC0706 – Clyde, Vic, 2007-08

This was the main trial used to screen candidate varieties.

Location
This trial was located near Clyde (approx: 38° 09′ 05″ S, 145° 20′ 38″ E) inside a dedicated bay separate from commercial bunching vegetable crops (Dutch Carrots, Bok-Choy, Bunching onions etc), on very light sandy black soil, typical of the region.

Design
Plots (Varieties) were replicated three times in randomized complete blocks. Plots consisted of two pair-planted rows (4 single rows in total) on a single bed 1.6 m wide (bed centre to adjacent bed centre), 2.0 metres long, with an average plant spacing of 35-38 mm. Beds were formed several days before planting.

Soil testing prior to planting showed ideal nutrient status for carrots with no deficiencies. No fertilizer or chemicals were applied.

All seed was hand planted on 07-08 Nov 2007, to a depth of about 5-10 mm by marking lines for rows, creating a shallow furrow with a vee-shaped aluminium tine, then sprinkling seed along furrows in excess of requirement and lightly covering furrows by hand.

Seedlings were thinned by hand on 03 Dec 2007, to approximately 35-40 mm, resulting in the final plant densities already indicated.

Irrigation was provided by solid set sprinklers arranged in a square grid pattern with 10 metres between risers, applying 8-10 mm once per day.

No fungicides or herbicides were applied and all weeding was done by hand.

Figure 7.1 *– BC0706: Trial layout*

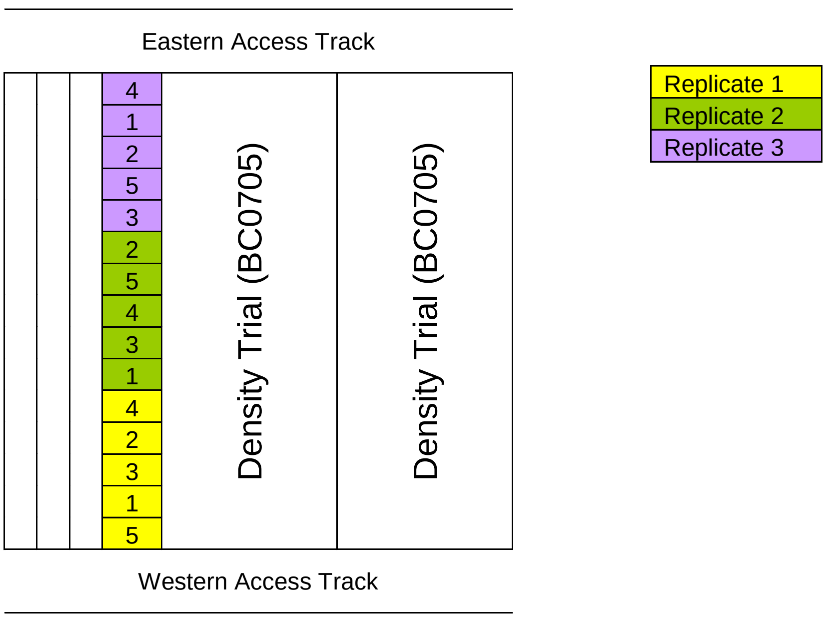


***Table 7.1** – BC0706: Seed Details*

Variety	No.	Description	Details Supplied	Supplied Seed Colour	Seed Treatment*
LX3632	**1**	Black (Current Standard)	Lot 2764/C Packed:5/07 Thiram treated	Pink (uneven)	AS + Apron XL 0.2 mL/100 g + Maxim XL 0.4 mL/100 g
LX254-7	**2**	New Black	Packed:9/07	Light orange-yellow (even)	AS
LX255-7	**3**	New Black	Packed:9/07	Light orange-yellow (even)	AS
LX256-7	**4**	New Yellow ("White")	Packed:9/07	Light orange-yellow (even)	AS
Red Hot	**5**	Orange (Current Standard)	ex. SDS Beverages	Pink (even)	AS

*Seed Treatment Details: AS = As Supplied, usually Thiram & Iprodione at "standard" rates.

Apron XL & Maxim XL were also applied at the above rates giving at total loading of 74 mg metalaxyl-m + 5 mg fludioxonil per 100 g of seed. These were not registered for use in carrots in Australia at the time the trial was conducted but were used to reduce the impacts likely to be caused by damping off pathogens.

Evaluation:

Photographs were taken at various stages between emergence and harvest. Bolting was assessed 08 Jan 2008 (61 DAP). Harvest assessments were carried out 13 Mar 2008 (126 DAP) by harvesting 0.50m of bed (all 4 carrot rows) and assessing bolting, carrot numbers, weights, cracking and deformities. After taking photographs of whole samples, entire plot yields were packed in plastic bags and sent by overnight road transport to SDS Beverages in Merbein. Only the black and purple varieties (1-3) were sent for evaluation. Here they were cool stored for a several weeks at 4° C, before being juiced. A 500 mL sample of juice was kept from each sample, frozen and subsequently analysed in SDS's Merbein laboratory for Brix using a refractometer and anthocyanin content using and absorbance spectrophotometer.

Statistical Analyses:
In all tables shown, vertical bars aligned in the same column indicate means that are NOT SIGNIFICANTLY DIFFERENT (LSD, P=0.05). Means followed by "-" failed Bartlett's Chi-squared Test for Homogeneity of Variance and attempts to rectify this with transformations were NOT successful (P=0.05). NSAP indicates no statistical analysis performed. Blue vertical bars indicate LSD results based on successfully transformed data BUT the numbers they follow are original.

BC0804 – Dareton, NSW, 2008

This was intended as a supplementary observation trial only. Small plots were hand seeded alongside a bolting study to determine whether the results of BC0706 were repeatable in the major growing region sown late in the season (compared with the very early timing in BC0706).

Location

This trial was located at the DPI Research Station, Dareton, NSW (approx: 34° 05′ 13″ S, 142° 00′ 53″ E), on previously uncultivated, red loamy sand, typical of the region.

Design

Plots (Varieties) were unreplicated. Plots consisted of two pair-planted rows (4 single rows in total) on a single bed 1.63 m wide (bed centre to adjacent bed centre), 2.0 metres long, with an average plant spacing of 35-38 mm. Beds were unformed but drainage was excellent. Varieties LX3632, LX255-7, the yellow LX256-7 & Red Hot were included but LX254-7 (purple) was not due to lack of seed.

Nutrition

15 Jan 2008: Hifert Single Superphosphate (0:9:0 N:P:K) applied at 500 kg/ha (45 kg P/ha). Hifert Sulfate of Potash (0:0:41:17 N:P:K:S) applied at 181 kg/ha (75 kg K/ha) & incorporated to 7 cm with disc harrows. Soil testing prior to planting showed good nutrient status for carrots apart from P which remained a little low even after the superphosphate application. Also, marginal trace element levels indicated a need for monitoring and if necessary applying these during crop development (nutrition data supplied in Section 5 for BC0801 is a relevant reference).

All seed was hand planted on 19 Mar 2008, to a depth of about 5-10 mm by marking lines for rows, creating a shallow furrow with a vee-shaped aluminium tine, then sprinkling seed along furrows in excess of requirement and lightly covering furrows by hand.

Seedlings were thinned a fortnight later to approximately 35-40 mm.

Irrigation was provided by solid set sprinklers arranged in a square grid pattern with 3.2 metres between risers. Rates and frequencies of irrigation were varied according to crop & seasonal demand.

No fungicides were used but the herbicides Linuron® 500 WG + Gesagard® 500 SC were applied at 2.2 Kg/ha + 2.2 L/ha respectively (Single jet, flat-fan knapsack sprayer at 250 L/ha output) 21 Feb 2008 several weeks prior to planting.

Results

BC0706 – Clyde, Vic, 2007-08

Table 7.2. *% Bolting 61 DAP & 126 DAP (Harvest)*

Variety	No.	% Bolting 61 DAP	Variety	No.	% Bolting 125 DAP
LX256-7	**4**	0.0 I	LX256-7	**4**	0.0 I
Red Hot	**5**	0.0 I	Red Hot	**5**	0.0 I
LX3632	**1**	1.0 I	LX3632	**1**	14.6 I
LX255-7	**3**	29.8 I	LX255-7	**3**	58.8 I
LX254-7	**2**	54.8 I	LX254-7	**2**	76.9 I
Transformation		None	Transformation		None

Figure 7.2. *% Bolting 61 DAP & 126 DAP (Harvest)*

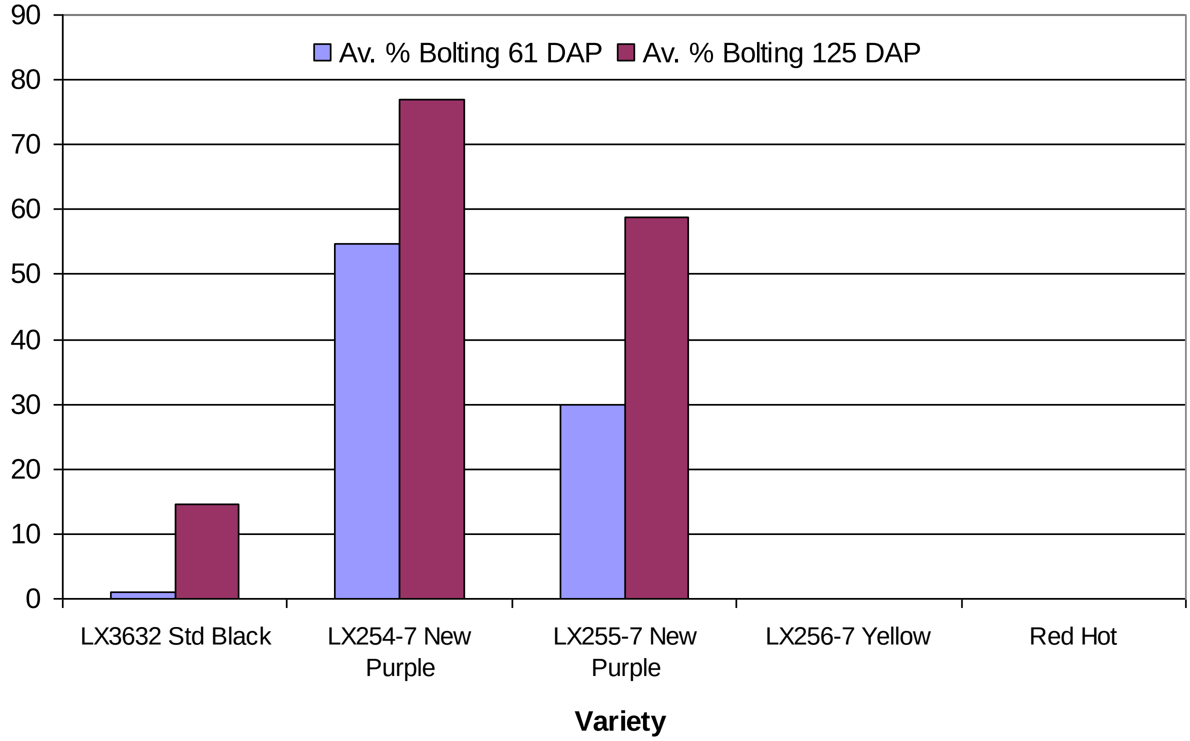


Table 7.3. *Average Plant Spacing (mm)*

Variety	No.	Av. Plant Spacing (mm)
LX255-7	**3**	35.2 I
LX256-7	**4**	35.5 I
LX254-7	**2**	37.3 I
Red Hot	**5**	37.6 I
LX3632	**1**	38.3 I
Transformation		None

Table 7.4. *Average Carrot Weight (g) & Average Crown Width (mm)*

Variety	No.	Av. Carrot Weight (g)		Variety	No.	Av. Crown Width (mm)	
LX256-7	**4**	111.6	I	LX256-7	**4**	33.7	I
Red Hot	**5**	94.9	I I	Red Hot	**5**	30.5	I I
LX3632	**1**	74.0	I I	LX3632	**1**	30.2	I I
LX255-7	**3**	64.5	I	LX255-7	**3**	28.3	I
LX254-7	**2**	56.0	I	LX254-7	**2**	26.0	I
Transformation		None		Transformation		None	

Figure 7.3. *Average Carrot Weight (g) & Crown Width (mm)*

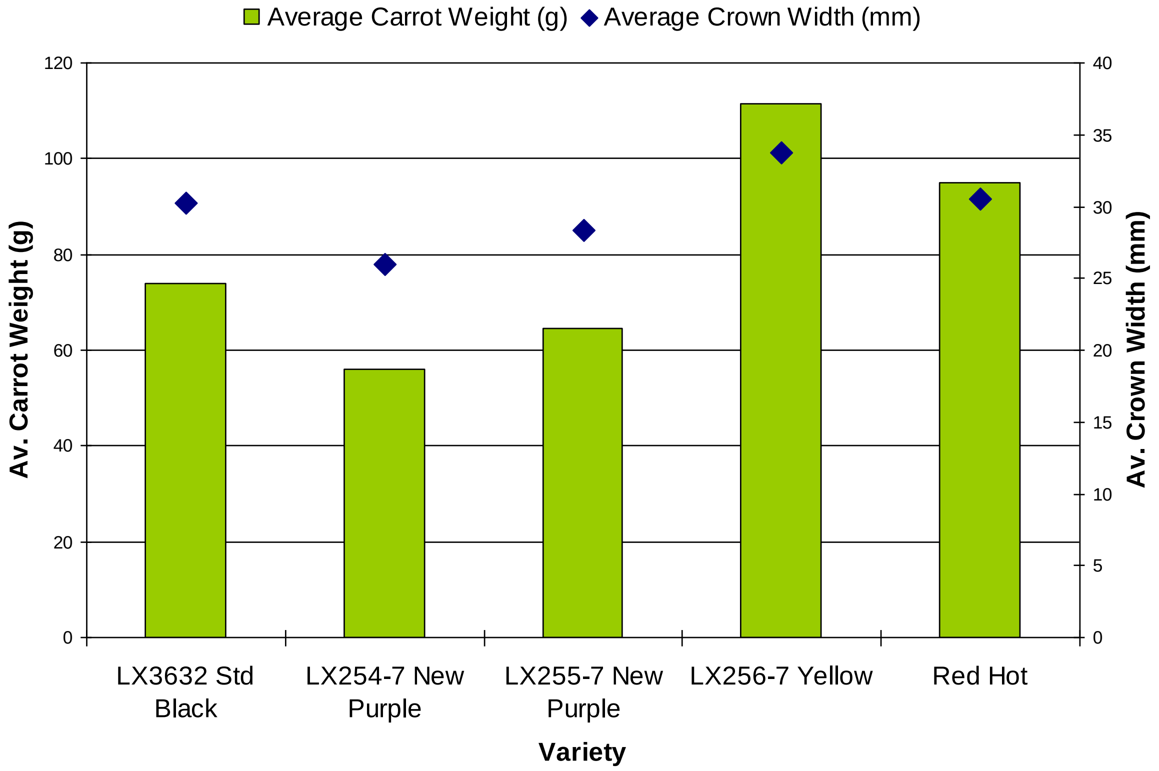


Table 7.5. *TOTAL Carrot Yield & Bolting Adjusted TOTAL Carrot Yield*

Variety	No.	Carrot Yield (t/ha)		Variety	No.	Adjusted Carrot Yield (t/ha)	
LX256-7	**4**	78.558	I	LX256-7	**4**	78.558	I
Red Hot	**5**	62.479	I	Red Hot	**5**	62.479	I I
LX3632	**1**	41.554	I	LX3632	**1**	48.667	I I
LX255-7	**3**	19.408	I	LX255-7	**3**	46.151	I I
LX254-7	**2**	8.917	I	LX254-7	**2**	37.287	I
Transformation		None		Transformation		None	

Figure 7.4. *Yield & Bolting Adjusted Yield (kg/ha)*

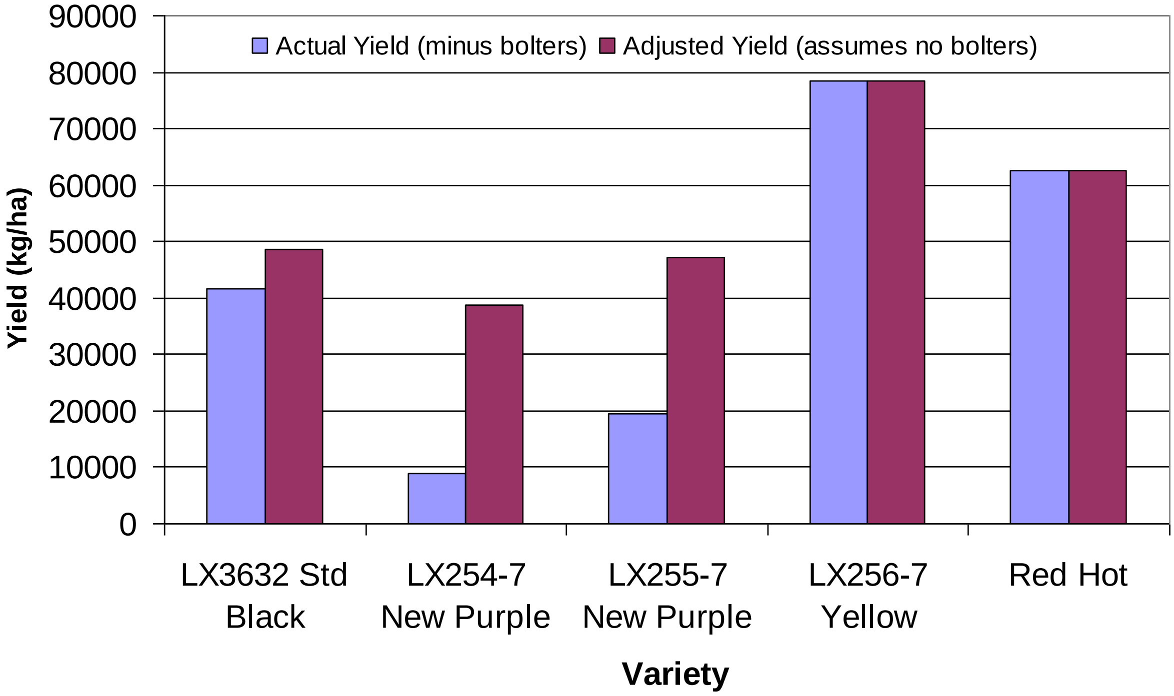


Table 7.6. *Bolting Adjusted Harvestable Carrot Yield and % Harvestable Carrot Yield (20+ mm crown width)*

Variety	No.	Harvestable Yield (t/ha) – 21+ mm	Variety	No.	% Harvestable Yield – 21+ mm
LX256-7	**4**	78.502 I	LX255-7	**3**	99.95 I
Red Hot	**5**	62.392 I I	LX254-7	**2**	99.94 I
LX3632	**1**	48.573 I I	LX256-7	**4**	99.93 I
LX255-7	**3**	46.124 I I	Red Hot	**5**	99.86 I
LX254-7	**2**	37.269 I	LX3632	**1**	99.76 I
Transformation		None	Transformation		Arcsine Square-root

Table 7.7. *Bolting Adjusted Harvestable Carrot Yield and % Harvestable Carrot Yield (26+ mm crown width)*

Variety	No.	Harvestable Yield (t/ha) – 26+ mm	Variety	No.	% Harvestable Yield – 26+ mm
LX256-7	**4**	78.281 I	LX255-7	**3**	99.71 I
Red Hot	**5**	62.087 I I	LX254-7	**2**	99.70 I
LX3632	**1**	48.412 I I	LX256-7	**4**	99.65 I
LX255-7	**3**	46.018 I I	LX3632	**1**	99.43 I
LX254-7	**2**	37.191 I	Red Hot	**5**	99.34 I
Transformation		None	Transformation		None

Table 7.8. *% Cracked Carrots & Average Cracks/Carrot*

Variety	No.	% Small	% Medium	% Large	% Very Large	% Cracked (All Sizes)	Av. Cracks/Carrot
LX254-7	**2**	0.0	0.0	0.0	0.0	0.0 I	0.00 I
LX255-7	**3**	0.0	0.0	0.0	0.0	0.0 I	0.00 I
LX256-7	**4**	3.5	0.0	0.0	0.0	1.2 I	0.01 I
LX3632	**1**	9.0	9.4	2.4	0.0	6.9 I	0.10 I
Red Hot	**5**	3.7	7.3	7.5	7.8	8.8 I	0.10 I
Transformation						None	None

Table 7.9. *% Carrots with Fibrous Roots, Side Shoots & Forking*

Variety	No.	% Carrots with Fibrous Roots	Variety	No.	% Carrots with Side-Shoots	Variety	No.	% Forked Carrots
LX254-7	**2**	0.0	LX256-7	**4**	1.17	LX255-7	**3**	2.9
LX255-7	**3**	0.0	Red Hot	**5**	1.31	LX256-7	**4**	4.7
Red Hot	**5**	0.0	LX255-7	**3**	1.45	Red Hot	**5**	5.0
LX256-7	**4**	1.2	LX3632	**1**	3.76	LX3632	**1**	6.7
LX3632	**1**	9.7	LX254-7	**2**	5.56	LX254-7	**2**	11.4
Transformation		Square-root	Transformation		-	Transformation		None

Table 7.10. *Brix, Anthocyanins (& Absorbance) – Varieties 1-3 only*

Variety	No.	°Brix	Variety	No.	Absorbance at 8.0° Brix & 538 nm	Variety	No.	Anthocyanins at 8.0° Brix (mg%)
LX255-7	**3**	10.97	LX254-7	**2**	0.338	LX254-7	**2**	34.83
LX254-7	**2**	10.13	LX3632	**1**	0.337	LX3632	**1**	34.67
LX3632	**1**	10.10	LX255-7	**3**	0.114	LX255-7	**3**	11.73
Transformation		None	Transformation		None	Transformation		None

***Table 7.11. Visual** Description of Variety Characteristics*

	LX3632	**LX254-7**	**LX255-7**	**LX256-7**	**Red Hot**
Principle Pigment	Anthocyanins	Anthocyanins	Anthocyanins	Lutein	Beta-carotone
Colour – Average Expression Level	Excellent c/w other black varieties	Good – more like LX3632 than LX255-7	Poor c/w other black varieties. More pink than purple-black.	Looks yellow but described as "white".	Orange (standard)
Colour Variability (b/w carrots)	High	High	High	Very low	Very low
Carrot <u>Cortex & Phloem</u> Colour Expression	Excellent	Excellent	Poor-moderate. Occasionally very good.	Relatively homogenous	Relatively homogenous
Carrot <u>Cambium</u> Colour Expression	Rarely any colour. Occasionally very good	Very rarely any colour. Occasionally moderate.	Very rarely any colour. Occasionally poor.	Lightly pigmented	Lightly pigmented
Carrot <u>Xylem</u> Colour Expression	Good, sometimes excellent	Poor, sometimes good	Poor, rarely good.	Relatively homogenous	Relatively homogenous
Carrot Shape	Imperator style but even longer and more gradually tapering	Strongly tapering, wider shoulders (More Kuroda or Chantenay style)	Tapering, wider shoulders (In between Imperator & Chantenay style)	Imperator style	Imperator type
Av. Carrot Size	Small	Small	Small	Large-Very Large	Large
Skin	Uneven, slightly rough, deeper lenticels & concentric grooves. Very prone to fibrous root development	Smooth, shallow lenticels and concentric grooves	Smooth, shallow lenticels and concentric grooves	Smooth, shallow lenticels and concentric grooves	Smooth, shallow lenticels and concentric grooves
Top Growth Vigour	High	High	High	Low	Low
Susceptibility to bolting	High	Very High	Very High	Very low	Very low

Discussion

Bolting (Table 7.2 & Figure 7.2)

While LX3632 was known to be substantially more prone to bolting through vernalization than standard orange carrots, such a high degree of bolting at such an early stage of development following relatively mild cold exposure, was not foreseen. Evidence of bolting was very obvious by 61 DAP (days after planting). LX3632 bolted much less severely than in the adjacent density trial sown 9-12 days earlier indicating a steep decline in bolting during this period (though still too severe for commercial planting). Further analysis of this data is covered in Section 3 of this report.

Bolting as estimated at 61 DAP, then from harvested plot transects at 125 DAP were closely correlated. At 77%, LX254-7 was significantly worse than all other varieties. LX255-7, though significantly better, was still severely affected by the early cold which caused 59% of plants to bolt. The current standard black LX3632 showed much less severe bolting at 15%, though still significantly less than either of the candidate purple varieties already described. Neither Red Hot nor the yellow variety LX256-7 bolted at all (significantly different to the three purple varieties).

Carrot Architecture – Average Weight, Width & Length (Tables 7.3-7.4 & Figure 7.3)

Average plant spacing was determined from harvest transect figures. These ranged from 35-38 mm across varieties and show that the hand thinning was sufficiently accurate to ensure any differences inside this range were not significant.

The yellow variety LX256-7 produced the largest carrots, with a significantly higher average carrot weight than all other varieties except Red Hot. The crown width of LX256-7, although 3 mm more than Red Hot, was not significantly higher than either Red Hot or LX3632. The candidate purple varieties showed the smallest crown widths and average carrot weights, although not significantly lower than the black standard LX3632.

The purple variety LX254-7 also showed a unique attribute towards harvest where many of the crowns on the larger carrots were exposed as the carrots seemed to lift spontaneously by perhaps 10-15 mm or so (Photo 7.5). This was presumably due to the shape of the carrot. This would potentially create a sunburn problem, although it was not evident in this case, perhaps because of the presence of anthocyanins. On the other hand it made the carrots far easier to harvest as the soil attachment significantly loosened.

Yield (Tables 7.5-7.7 & Figure 7.4)

Bolting carrots were counted as unharvestable and unmarketable. To adjust for forgone yield where bolting occurred yields were increased proportionally, based on the harvestable yields collected in each plot. The resulting figure was called “(bolting) adjusted” yield. Very few carrots recovered from plots were less than 21 mm diameter at the widest part of the crown (generally less than about 0.1%) and there were no significant differences between varieties. Even when a 26 mm minimum crown diameter was imposed as a minimum harvestable specification, the unharvestable proportion was only about 0.3-0.7% of total yield and again no differences between varieties were significant. Proportions were based on adjusted carrot yields but because the total weights of carrots under 26 mm was in all cases small, harvestable yields were essentially identical to adjusted carrot yield and so were the statistical trends as detailed below.

Varietal performance trends in actual yield and bolting adjusted yields were the same despite the most severely affected variety LX254-7 losing 77% of potential yield to bolting. This also lends weight to the method used to adjust yield as being sound.

With an adjusted yield of around 79 t/ha, the yellow variety LX256-7 was significantly higher than all varieties except Red Hot, which at 62 tonnes/ha was still 17 tonnes/ha less. Red Hot was the next highest yielding variety, though bolting adjustments only lead to a significantly better yield than the poorest yielding (highest bolting) variety LX254-7. The current standard black variety LX3632 yielded about 49 tonnes/ha after adjusting for the relatively low level of bolting, putting it at about 13 tonnes/ha behind or about 21% less than Red Hot. The new purple candidate variety LX255-7 produced about 3 tonnes/ha or about 5% less than the black standard LX3632 but only after a major adjustment for bolting. At around 37 tonnes/ha after adjusting for the most severe level of bolting, the other candidate purple variety LX254-7 was the poorest yielding variety, around 9 tonnes/ha or 19% less than the better candidate purple variety LX255-7.

Cracking (Table 7.8)

Examination of material being commercially processed as well as results in this trial shows that cracking is a significant problem in conventional B-carotene carrots like Red Hot. This seems mainly to be associated with variability in moisture availability but other factors such as variety and excessive use of Nitrogen also appear to have an effect.

The variability between replicates resulted in no significant varietal differences in cracking. Distribution patterns showed some plots were more severely affected than others. The results suggest moisture was the main contributor to cracking. Differences in cracking appeared loosely correlated with the ratio of carrot to canopy weights. While the two candidate purple varieties had very vigorous tops (canopy), bolting was so severe that very few carrots were produced, so more moisture was available to individual carrots. As a result, no cracks were found in these varieties. The yellow variety LX256-7 had a very high carrot yield but the least vigorous tops of any variety and produced the least cracking among the three highest yielding varieties. The worst cracking occurred in the standard black variety LX3632 and Red Hot. Red Hot produced more carrots with a smaller canopy, while LX3632 produced less yield with much more vigorous tops giving a similar result overall.

Carrot Disease & Deformities (Table 7.9)

Forking has been quite severe historically on this block. Recent attempts by the grower to identify the likely causes indicated that nematodes were not present and that *Pythium* was the most likely cause. Cavity spot (also *Pythium*) was found extensively but was very difficult to see clearly on the high anthocyanin carrots. The yellow LX256-7 appeared somewhat more resistant than Red Hot but other varieties did not appear strongly divided and disease level was not formally assessed.

A range of deformities were recorded. Although none of them were significantly linked to particular varieties, LX3632 and particularly LX254-7 did appear to be more severely forked when it was observed, i.e. the frequency was not especially different to Red Hot for example but they were more severely affected when it did occur. The production of coarse fibrous roots was significantly and almost exclusively associated with the black standard LX3632. While it appears as if this may simply be a lesser manifestation of more major branching recorded, the specific cause might be identified in future work focused on disease control.

Brix & Anthocyanins – Black & Purple Varieties Only (Table 7.10)

Brix
Sample variance for Brix of juice was high within varieties but just sufficiently homogenous for analysis without data transformation. Differences between varieties were not significant however. Brix at 10-11 was good but not exceptional.

Anthocyanins
Differences between individual carrot anthocyanin levels in plot samples was considerable, so entire samples harvested from plots were juiced to minimise variance. The standard black LX3632 & the purple LX254-7 returned about three times (significant) the anthocyanin content of the other purple LX255-7. These differences were visible (see cross section photographs), though the standard black LX3632 did appear slightly "blacker" on average than LX254-7.

Visual Characteristics (Table 7.11)

These require no special qualification and should be viewed in conjunction with photos in Appendix 2.

BC0804 – Dareton, NSW, 2008

Bolting
None of the carrots in this trial showed the same "early" bolting (bolting before 10 weeks) seen in BC0706. Conditions were warm to hot for the first 4-6 weeks of crop growth. This indicated a particular susceptibility to early bolting through early growth exposure to cold that existed in the two high anthocyanin lines screened (LX3632 & LX255-7) but not in the Red Hot (orange) or yellow (LX256-7). However, as plants were allowed to grow through the coldest months of the year, all were extensively bolting by 198 days after planting ("late" bolting).

Carrot Architecture – Average Weight, Width & Length
Carrots were quite varied in size with a higher proportion of smaller carrots than in BC0706. Proportions were normal though with a higher number of small carrots, they tended to be particularly spindly across all varieties. All carrots seemed to have a minimum heat unit requirement during early development to grow large carrots and tops. This was particularly evident when LX3632 was compared with an adjacent planting made 15 days later (03 Apr 2008).

Top Growth
The most striking observation early in the trial was the relatively slow and inhibited top growth of all varieties compared with adjacent trials planted in the heat of summer. However, the pattern of top growth was similar to BC0706 with the two high anthocyanin lines (LX3632 & LX255-7) showing much more vigorous tops than Red Hot (orange) or yellow (LX256-7).

Growth Deformities & Cracking
There were virtually no symptoms of any growth deformities, cracking.

Yield, Brix & Anthocyanins
As carrots were generally undersized, no formal yield assessments were performed. For the same reasons, Brix was not tested and anthocyanin development was visually gauged only. Anthocyanin development reflected the observations of BC0706 with greater expression in LX3632 than LX255-7.

Photographs

Detailed photographs of varieties can be found in Appendix 2.

Photo 7.1 *- BC0706, Clyde, Vic, 2007-08. Clear variety differences in bolting only 61 DAP. (from left to right: LX256-7, LX254-7, LX255-7, LX3632, Red Hot). Arrows indicate ends of plots.*

Photo 7.2 *- BC0706, Clyde, Vic, 2007-08. Severe Cavity Spot in some plots, especially evident on Red Hot but hard to see on the high anthocyanin varieties.*

***Photo 7.2** - BC0706, Clyde, Vic, 2007-08. LX3632 showed significantly more fine fibrous roots than other varieties. Cavity Spot was hard to see on the high anthocyanin varieties. The high anthocyanin carrots appeared to show more severe forking but not a significantly higher frequency of forking.*

***Photo 7.3** - BC0706, Clyde, Vic, 2007-08. Severe Cavity Spot in some plots, somewhat less evident on LX256-7 than Red Hot.*

Photo 7.4 *- BC0706, Clyde, Vic, 2007-08. LX3632 showing fine & coarse fibrous roots, forking and severe growth cracking.*

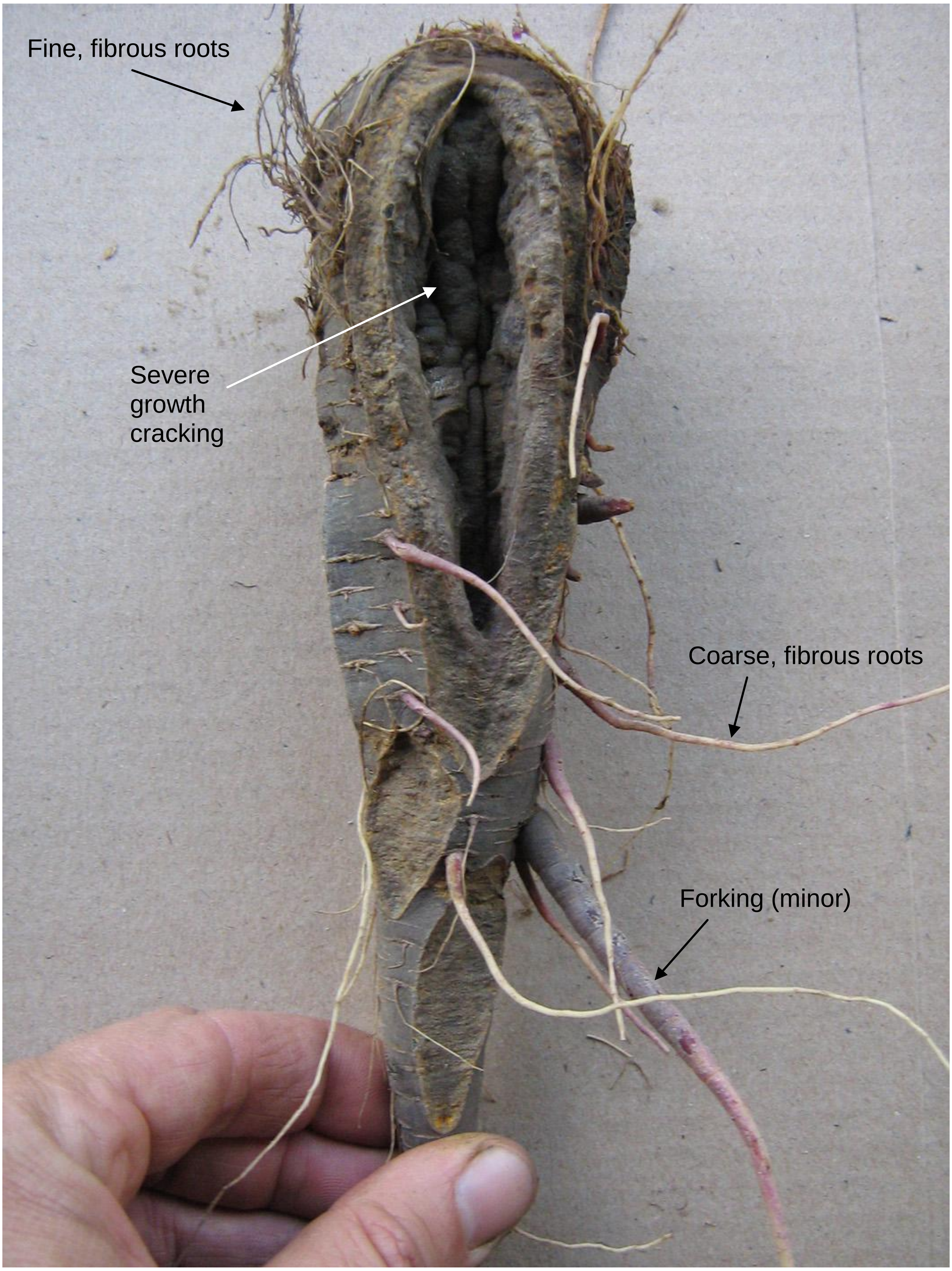


Photo 7.5 *- BC0706, Clyde, Vic, 2007-08. LX254-7 showing unique tendency of this variety for the crown to lift during late maturity, exposing the crown but also making harvesting easier.*

8 Prospective New Black Carrot Production Regions

Introduction

The carrot juicing industry up to now has been based in south-eastern Australia. The low margins for conventional carrot juice has meant that much of the production comes from rejected fresh market carrots (forked, misshapen or size based) rather than just dedicated juicing crops. The low margin has also meant production close to the factories has been far more attractive because of lower freight costs.

It was anticipated that the bulk of any new black carrot production would also come from south-eastern Australia and for this reason, along with easier access for frequent visits, the bulk of the trials were carried out in this region. However, in the first season of the project a number of trials were carried out in prospective northern production areas. The aim was to see how black carrot yield and quality compared in these areas, with a view to producing a higher value product which might therefore justify freight costs, outside of the southern (summer) production season.

These trials were generally dual-purpose. They were primarily observation trials but also used to help address some of the other key issues such as nitrogen use and the efficacy of plant growth regulators. They were also valuable in providing key data for the bolting work summarized in Section 3.2.

This section provides a quick reference on the relative performance of crops in these areas and the likely planting windows, based on the bolting model developed in Section 3.2.

Key Outcomes

- Production of LX3632 in traditional southern Australian growing regions remains tightly constrained by the carrot's extreme sensitivity to early bolting. On current indications, at best this is a 2-3 month window covering the hottest period of the year.

- Northern production regions offer a significant extension to the currently constrained planting periods for traditional southern production. If crop value can justify freight costs, there are sufficient suitable locations in mainland Australia for year-round production of LX3632.

- The northern limit to successful LX3632 production lies in regions with a climate similar to or intermediate between Katherine and Bowen. Darwin was found to be unsuitable.

- Brix and anthocyanin production from northern region crops appears to be at least comparable with southern crops. High yields and average carrot weights seem to be the biggest challenge or at least warrant further work to clarify the suitability of northern region production.

- A number of other prospective production regions in mainly coastal Queensland offer the most likely path to scheduled cool season production of LX3632.

- The Mallee regions of SA, Victoria and NSW represent the southernmost production regions for LX3632. While some crops were successfully grown without significant bolting at the hottest time of the year in southern (coastal) Victoria, climate is marginal and the planting window restricted to not more than about 4 weeks.

- Tasmania is unsuitable for production of LX3632 as average day temperatures are likely to induce bolting at all times of the year.

- Caution is recommended in southern regions for late summer – early autumn plantings. Inadequate early accumulation of heat units often results in poor, low yielding crops even if heat in the first 3-4 weeks is sufficient to prevent early bolting.

Materials & Methods

BC0702 – Bowen, Qld, 2007 (See Section 6)

BC0703 – Katherine, NT, 2007 (See Section 5)

BC0704 – Darwin, NT, 2007

Location
This trial was located near Darwin, at the NTDPI Coastal Plains Research Station (approx: 12° 35′ 42″ S, 131° 18′ 16″ E, elevation 16m) inside a dedicated trial area specially worked for the purpose and a red clay loam typical of the region.

Design
Single bed plots, each 30m long were planted with seed tape on three separate dates (09 May 2007 & 30 May 2007 & 20 Jun 2007). There were two pair-planted rows (4 single rows in total) on a single bed 1.6 m wide (bed centre to adjacent bed centre).

Soil testing prior to planting showed ideal nutrient status for carrots with no deficiencies.

Beds were semi-formed and soil was well prepared several days before planting. All seed was planted, to a depth of about 5-10 mm using seed tape. Exposed tape was lightly covered by hand.

No thinning was conducted. Emergence was somewhat uneven due to varied seed viability. A different spool of seed tape used for the last planting gave substantially improved germination.

Irrigation was provided by drip-lines – One between each pair of rows. Irrigation intervals were determined by the cooperator and scheduled as for the rest of the farm, typically a single application of 6-12 mm/day once a day.

No fungicides or herbicides were applied and all weeding was done by hand.

Evaluation
Photographs were taken at various stages between emergence and harvest. Only plots from the third planting were harvested 105 days after planting, on 03 Oct 2007 (147 & 126 days after plantings 1 & 2 which were too mature for harvest). Calculating the yield from these plots was not possible due to the very uneven stands. The older two planting in particular were largely rotting below the ground. Plot samples were packed in plastic bags and sent by overnight road transport to SDS Beverages in Merbein. Here they were cool stored for several days at 4° C, before being juiced and subsequently analysed in SDS's Merbein laboratory for Brix using a refractometer and anthocyanin content using an absorbance spectrophotometer.

Results

The data presented in this section is a summary of key figures. For complete results see Section 5 (BC00703) & Section 6 (BC0702). Results for BC0704 are all presented in this Section.

***Table 8.1** – Key Harvest Results from Northern Australian Trials and Southern Australian reference Sites.*

Site	Plant Date	Crop Age At Harvest (Days)	TOTAL Yield (t/ha)	Av. Weight (g)	Brix (°Br)	Antho-cyanins (mg%@ 8.0°Br)	Comments
BC0702 Bowen Qld	02/05/7	200					Too mature for yield
	25/05/7	177					Too mature for yield
	17/07/7	124	*45 (42-49)*	*143 (135-155)*	10.3 (10.1-10.5)	90 (46-125)	Yield from 50 carrots not set plot length due to uneven plant stand.
BC0703 Katherine NT	24/05/7	130	24 (13-33)	45 (24-71)	12.0 (10.8-13.1)	87 (56-123)	
	14/06/7	109	22 (15-26)	40 (27-52)	11.5 (11.2-11.8)	48 (36-68)	
BC0704 Darwin NT	09/05/7	147					Many rotten
	30/05/7	126					Many rotten
	20/06/7	105	*15 (15-20)*	*40 (20-60)*	*9.5*	*low*	Some rotten
Southern Reference 1 BC0706 Clyde Vic	17/11/7	126	49	74	10.1	35	
Southern Reference 2 BC0901 Clyde Vic	03/02/9	175	32-60	51-77	10.1-11.0	68-83	
Southern Reference 3 BC0801 Dareton NSW	23/01/8	145	43-58	90-116	8.9-10.0	19-36	
Southern Reference 4 BC0902 Dareton NSW	26/01/9	171	45-49	53-66	9.5-10.6	77-99	

***NB**: Estimated or extrapolated figures are italicized.*

Climate Data for Potential LX3632 Production Regions

The climate data in the following three pages shows the long term daily maximum, minimum and average temperatures for each month indicated, over a range of climatic regions that carrots might be grown in, including those where trials were conducted over the course of the project. Based on the findings presented in Section 3.2 of this report, planting periods likely to result in significant bolting are indicated as follows:

Av. Daily Temperature is 16.0°C or less - DO NOT PLANT
Av. Daily Temperature is 16.1-18.0°C - BOLTING VERY LIKELY
Av. Daily Temp is 18.1-19.5°C – SOME BOLTING POSSIBLE
Av. Daily Temperature is 19.6°C or greater – SIGNIFICANT BOLTING UNLIKELY

THIIS DATA IS INTENDED AS A GUIDE ONLY. THE ACTUAL LEVELS OF BOLTING EXPERIENCED MAY BE MODIFIED BY OTHER FACTORS. ACTUAL TEMPERATURES EXPERIENCED WILL PROVIDE A MORE RELIABLE GUIDE TO BOLTING IN INDIVIDUAL CROPS.

While the cardinal temperature used for the upper limit to bolting is 16.0°C, individual days with averages below this level may occur in months with slightly higher average day temperatures. The 16.1-18.0°C & 18.1-19.5°C ranges have been flagged for this reason and are based on actual observations of LX3632 crops over the life of the project.

It is also important to remember that these critical periods relate only to the risk of bolting. For those areas where a critical cold period occurs, it is safer to plant after this time rather than in a window of opportunity before this period, particularly if it is extended as in Southern Australia. This is because crops appear to need a critical minimum period of heat units to be accumulated during early crop development in order to produce a high yielding crop. This will require further evaluation beyond the current project.

The Data Below was extracted from the **Australian Bureau of Meteorology** website.

014015 DARWIN AIRPORT, NT														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	31.8	31.4	31.9	32.7	32.0	30.6	30.5	31.3	32.5	33.2	33.3	32.6	69	1941
Minimum (°C)	24.8	24.7	24.5	24.0	22.1	19.9	19.2	20.4	23.0	24.9	25.4	25.3	69	1941
Average (°C)	**28.3**	**28.1**	**28.2**	**28.4**	**27.1**	**25.3**	**24.9**	**25.9**	**27.8**	**29.1**	**29.4**	**29.0**		

014903 KATHERINE AV. MUSEUM, NT														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	34.7	34.0	34.3	34.1	32.2	30.2	30.4	32.4	35.9	37.8	37.5	36.0	25	1946
Minimum (°C)	24.2	23.9	23.1	20.8	16.7	14.0	12.8	14.6	20.0	23.7	24.7	24.6	25	1946
Average (°C)	**29.5**	**29.0**	**28.7**	**27.5**	**24.5**	**22.1**	**21.6**	**23.5**	**28.0**	**30.8**	**31.1**	**30.3**		

033257 BOWEN AIRPORT, Qld														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	31.5	31.3	30.9	29.3	27.2	24.9	24.5	25.4	27.4	29.3	30.5	31.4	21	1987
Minimum (°C)	23.9	23.9	22.8	20.9	18.1	15.1	13.5	14.3	16.4	19.9	22.2	23.5	21	1987
Average (°C)	**27.7**	**27.6**	**26.9**	**25.1**	**22.7**	**20.0**	**19.0**	**19.9**	**21.9**	**24.6**	**26.4**	**27.5**		

The Data Below was extracted from the **Australian Bureau of Meteorology** website.

039083 ROCKHAMPTON AERO, Qld														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	31.9	31.2	30.5	28.8	26.0	23.5	23.1	24.8	27.3	29.7	31.2	32.1	71	1939
Minimum (°C)	22.1	22.1	20.8	17.9	14.2	10.9	9.5	10.6	13.6	17.0	19.5	21.2	71	1939
Average (°C)	**27.0**	**26.7**	**25.7**	**23.4**	**20.1**	**17.2**	**16.3**	**17.7**	**20.5**	**23.4**	**25.4**	**26.7**		

039128 BUNDABERG AERO, Qld														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	30.1	29.9	29.1	27.4	24.7	22.6	22.0	23.3	25.4	26.9	28.3	29.4	32	1959
Minimum (°C)	21.5	21.4	19.9	17.5	14.2	11.6	10.1	10.9	13.7	16.6	18.9	20.5	32	1959
Average (°C)	**25.8**	**25.7**	**24.5**	**22.5**	**19.5**	**17.1**	**16.1**	**17.1**	**19.6**	**21.8**	**23.6**	**25.0**		

040436 GATTON QDPI RES. STN., Qld														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	31.6	30.7	29.7	27.2	23.8	21.1	20.7	22.3	25.5	28.1	29.8	31.4	37	1968
Minimum (°C)	19.3	19.3	17.4	14.1	10.9	7.6	6.2	6.8	9.6	13.1	15.8	18.2	37	1968
Average (°C)	**25.5**	**25.0**	**23.6**	**20.7**	**17.4**	**14.4**	**13.5**	**14.6**	**17.6**	**20.6**	**22.8**	**24.8**		

GRAFTON RESEARCH STATION, NSW														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	30.1	29.8	27.7	25.7	22.9	20.6	20.1	21.6	25.2	27.4	28.4	30.1	17	1917
Minimum (°C)	18.5	18.6	17.1	14.2	10.0	7.7	6.1	6.8	10.0	13.0	15.6	17.8	16	1917
Average (°C)	**24.3**	**24.2**	**22.4**	**20.0**	**16.5**	**14.2**	**13.1**	**14.2**	**17.6**	**20.2**	**22.0**	**24.0**		

009067 UPPER SWAN RES. STN., WA														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	33.6	33.8	31.1	26.4	22.0	19.0	18.0	18.4	20.5	23.6	27.1	31.2	24	1965
Minimum (°C)	15.0	16.2	14.3	11.5	9.4	8.3	7.6	6.8	7.5	8.6	10.8	13.0	24	1965
Average (°C)	**24.3**	**25.0**	**22.7**	**19.0**	**15.7**	**13.7**	**12.8**	**12.6**	**14.0**	**16.1**	**19.0**	**22.1**		

075041 GRIFFITH AIRPORT AWS, NSW														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	32.8	32.1	28.8	24	19.3	15.5	14.4	16.5	19.8	23.8	28	30.8	35	1970
Minimum (°C)	16.9	17.3	14.2	10.2	7.2	4.5	3.5	3.9	5.8	8.9	12.5	15.1	35	1970
Average (°C)	**24.9**	**24.7**	**21.5**	**17.1**	**13.3**	**10.0**	**9.0**	**10.2**	**12.8**	**16.4**	**20.3**	**23.0**		

076031 MILDURA AIRPORT, Vic														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	32.2	31.6	28.4	23.5	19.0	16.0	15.3	17.2	20.4	23.8	27.4	30.1	64	1946
Minimum (°C)	16.6	16.4	13.8	10.1	7.4	5.2	4.3	5.2	7.4	9.8	12.5	14.8	64	1946
Average (°C)	**24.4**	**24.0**	**21.1**	**16.8**	**13.2**	**10.6**	**9.8**	**11.2**	**13.9**	**16.8**	**20.0**	**22.5**		

The Data Below was extracted from the **Australian Bureau of Meteorology** website.

025509 LAMEROO COMPARISON, SA														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	30.9	30.5	27.6	22.9	18.6	15.6	15.0	16.4	19.4	22.5	26.1	28.9	95	1915
Minimum (°C)	13.3	13.5	11.5	9.0	7.0	5.1	4.4	4.8	6.0	7.8	10.0	12.1	95	1914
Average (°C)	**22.1**	**22.0**	**19.6**	**16.0**	**12.8**	**10.4**	**9.7**	**10.6**	**12.7**	**15.2**	**18.1**	**20.5**		

009573 MANJIMUP, WA														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	27.1	27.0	24.7	21.0	17.6	15.2	14.3	14.9	16.4	18.7	21.8	24.8	70	1936
Minimum (°C)	13.0	13.3	12.5	10.7	8.9	7.4	6.4	6.5	7.2	8.3	10.1	11.6	71	1936
Average (°C)	**20.1**	**20.2**	**18.6**	**15.9**	**13.3**	**11.3**	**10.4**	**10.7**	**11.8**	**13.5**	**16.0**	**18.2**		

086375 CRANBOURNE BOT. GDNS., Vic														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	25.2	25.6	23.4	19.8	16.3	14.0	13.3	14.5	16.4	18.7	21.0	23.3	20	1990
Minimum (°C)	13.4	14.0	12.3	10.2	8.5	6.7	6.1	6.3	7.7	8.8	10.3	11.7	20	1990
Average (°C)	**19.3**	**19.8**	**17.9**	**15.0**	**12.4**	**10.4**	**9.7**	**10.4**	**12.1**	**13.8**	**15.7**	**17.5**		

091126 DEVONPORT AIRPORT, Tas														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	21.2	21.6	20.3	17.6	15.3	13.3	12.7	13.1	14.1	15.7	17.7	19.5	18	1991
Minimum (°C)	12.2	12.6	10.8	8.6	6.8	5.1	4.6	5.0	6.0	7.3	9.0	10.5	18	1991
Average (°C)	**16.7**	**17.1**	**15.6**	**13.1**	**11.1**	**9.2**	**8.7**	**9.1**	**10.1**	**11.5**	**13.4**	**15.0**		

091091 SHEFFIELD, Tas														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Years**	**Start**
Maximum (°C)	21.0	21.5	19.5	16.3	13.6	11.3	10.6	11.4	13.0	15.5	17.2	19.2	30	1965
Minimum (°C)	10.0	10.3	8.8	6.7	4.7	2.9	2.5	3.2	4.3	5.6	7.1	8.7	30	1965
Average (°C)	**15.5**	**15.9**	**14.2**	**11.5**	**9.2**	**7.1**	**6.6**	**7.3**	**8.7**	**10.6**	**12.2**	**14.0**		

Discussion

Darwin, NT (BC0704)
This was the northernmost site where LX3632 was evaluated. It established an upper limit to sustained warmth and humidity tolerated by LX3632. As the climatic data shows, there is no period during the year in this climate that risks triggering early bolting from vernalization.

However, as Table 8.1 shows, even at 105 days which is still immature in a southern crop, various rots had started to take a significant toll on the crop. This became progressively worse in successively older plantings with high numbers of rotten carrots in the 126-147 day old plantings. In addition there was a high frequency of gall structures consistent with the kind of damage caused by root-knot nematode. There were also a lot of carrots with enlarged lenticels which may have been related to irrigation more than nematodes.

Carrot size was fair but not especially good and yields were low mainly due to the rots already described. Many of the carrots were extremely broad and stumpy although forking was not particularly severe compared with some southern crops grown.

Although only visually assessed, anthocyanin development was not especially good due to the young age of the material in the third planting. The few carrots that could be recovered from the earlier plantings did show better colour development.

Katherine (BC0703)
A significant improvement in crop quality occurred when LX3632 was grown in Katherine instead of Darwin. The lighter, free draining soil at Katherine played a key role in producing less forking and an absence of rots. Climate data shows cooler nights during the planting period but still well above the bolting danger threshold. Lower humidity inland would also have some benefit in reducing foliar disease pressure, although this was not found to be a particular problem at any of the northern sites.

Table 8.1, shows yields were still low compared to southern crops, though better than Darwin. Average carrot weight was also low but Brix and anthocyanin development in the most mature crop (130 days) was very good. The less mature planting (109 days) had very similar Brix but only about half of the anthocyanin development, showing the dramatic increase in levels between about 110 & 130 days.

Despite the low yields, it would be of value to retrial a crop in this area as the quality was good and it could be a valuable centre for winter sown production if product value ever justifies the added freight costs.

Bowen (BC0702)
There were three planting dates with a considerable gap between the second and third plantings. This was because unseasonal rain and heavy soil caused waterlogging, that caused a delay in sowing between 25 May 2007 & 17 Jul 2007.

The climate data shows July to be the only marginal risk period for bolting. The actual weather data from the trial shows plantings 2 & 3 accumulated 2.6 & 3.8 vernalizing Cd (thermal days) in the first 4 weeks. No early bolting was seen in these crops. However, there was still adequate chill over the whole cropping cycle to induce late bolting in planting 1 in less than 200 days. This puts any (theoretical) plantings between the actual plantings made 25 May and 17 Jul close to, but just below, the estimated 5.0-10 Cd threshold arrived at in Section 3.2 to induce early bolting.

Crop yields and carrot weights need to be viewed with caution. The poor viability of seed on the tape used made for very uneven plant stands and the unusual method used for harvesting where 50 plants were harvested rather than a set length of plot.

However, of all three northern experimental sites evaluated, Bowen seemed to show the greatest promise. Yield, average carrot weight, Brix and anthocyanins were all very good. As with Katherine, this could be a suitable winter production region if freight costs can be justified with some caution required for planting in July. The most important limitation is likely to be soil structure and drainage. So any lighter soils that exist in the region would be most suitable.

Tasmania (BC0700)
Tasmania warrants a special mention due to its lack of suitability for production of LX3632 at any stage in the year. The bolting model developed in Section 3.2, coupled with the climate data shown for two locations on the north coast (Devonport & Sheffield) show there are no safe windows for sowing to avoid bolting.

This was born out from observations and measurements made on a commercial crop of LX3632 grown and harvested immediately prior to the project commencing (BC0700). Here, a November sowing resulted in an accumulated 45.7° Cd in the first three weeks after planting, well above the estimated 7.9° Cd requirement for early bolting established in Section 3.2. The details from this study can be found in Appendix 1.

Western Australia
No trials were carried out in this state. However, climate data for Manjimup in the south and the Upper Swan (just north of Perth) is shown. The likely safe window for planting LX3632 at Manjimup is probably somewhere inside Jan-Feb, while at Upper Swan inside Dec-Mar. Caution is recommended at the later end of these windows to ensure sufficient heat unit accumulation for good crop development.

Key LX3632 Production Areas Evaluated during the Project

These areas are characterized by a short safe sowing window, relatively high yields and average carrot weights but variable Brix and anthocyanin levels not easily related to any particular climatic factor. Detailed analyses of all trials from these areas are covered elsewhere in this report.

South Australia
The Lameroo data shows climate data relevant for the southern Mallee, such as Parilla where many trials were conducted. The single most remarkable discrepancy in reviewing the bolting data was significant early bolting that resulted from a 10 Dec 08 planting (BC0805). Data shows this crop should only have accumulated 0.8° Cd in the first week, substantially less than the estimated 7.9° Cd required for early bolting. There may have been localized effects that did not occur at the weather station but the exact cause remains uncertain.

Nonetheless, the long term data suggests a safe window is somewhere inside the Dec-Feb period. March plantings should be avoided due to the rapid onset of cold weather in April. This presents the dual dangers of early bolting and inadequate accumulation of early heat units for crop development.

Production in the northern Mallee (Riverland) area is better guided by Mildura climate data.

Mildura & Griffith
This has been a very large part of the traditional processing carrot production area also taking in Robinvale in Victoria. The climate across this wide production region shows little variation. It indicates a sowing window might start as early as November and run through to February. Again caution would be advised for any March plantings to avoid the dangers of inadequate heat accumulation and rapidly cooling weather causing early bolting. The trials conducted in this region were at Dareton, NSW with a preliminary investigation of a commercial crop at Robinvale (BC0701) early on in the life of the project. The details from this latter study can be found in Appendix 1.

9.1 *Effect of Disease on Emergence, Establishment, Yield & Harvest Quality*

Introduction

Other than bolting, poor plant establishment was clearly identified early on in this project as the most important area to address to improve crop yields. The causes were not clearly known and a range of biotic and abiotic factors needed to be investigated.

The principle diseases causing poor emergence in carrots suspected were the usual damping off diseases – *Fusarium* spp., *Pythium* spp. & *Rhizoctonia* spp. A recent study (Coles & Wicks, 2003) had also identified *Alternaria radicina* to be a previously unidentified cause of poor carrot establishment. It was also a potential cause of the poor establishment seen in black carrot crops.

Early project and pre-project observations suggested *Sclerotinia*, was a major foliar disease problem of black carrots. Crops also appeared to suffer from more severe foliar *Alternaria dauci* infections than ordinary orange carrots.

Two sets of trials were initiated:

1. **Plant emergence & establishment**: three field trials were established to see which, if any of these diseases were implicated in poor plant establishment and whether seed and soil treatments with fungicides were effective. Treatments were divided between those with no activity against *Pythium* spp., those with activity against *Pythium* spp. only (contain metalaxyl-m) and those with activity against Pythium as well as a wide range of other prospective diseases (*Fusarium* spp., *Rhizoctonia* spp., and *Alternaria* spp.).

2. **Effects of soil-borne diseases on harvest quality & yield**: A trial was also established in soil known to have recurrent problems with cavity spot (*Pythium* spp.) to see what effects this disease was having on harvest quality and again whether more sustained applications of fungicides improved harvest quality. Treatments were divided between those with no activity against *Pythium* spp., those with activity against *Pythium* spp. only (contain metalaxyl-m) and those with activity against *Pythium* as well as a wide range of other prospective diseases (*Fusarium* spp., *Rhizoctonia* spp., and *Alternaria* spp.).

   A smaller, simpler, second trial was established at Dareton, NSW on a site where disease levels were expected to be low.

High rates of fungicides were used in these studies (some NOT currently registered for use in carrots). The activity spectra for each is detailed below:

Metalaxyl-m – *Pythium* spp.

Azoxystrobin – *Pythium* spp., *Rhizoctonia* spp., *Fusarium* spp., *Alternaria* spp.

Fludioxonil – *Rhizoctonia* spp., *Fusarium* spp., *Alternaria* spp.

In addition, the role that nematodes might play in affecting carrot quality was also investigated by relating harvest qualities from various studies to nematode loads isolated at those sites.

Key Outcomes

- Soil-borne and seedling diseases were NOT found to be the principle cause of poor black carrot establishment in the major production regions of Southern Australia. None of the aforementioned diseases clearly affect germination or establishment of black carrots more severely than they affect standard orange types like Apache.

- Foliar diseases were not found to be a more serious cause of yield loss or reduced harvest quality for LX3632 than for ordinary orange carrots.

  Sclerotinia can severely infect black carrots. The larger and more vigorous canopies of black carrots may make them more susceptible under favourable conditions (eg. Tasmania) but the disease appears to be well managed under more typical summer plantings on mainland Australia.

  Alternaria leaf blight was seen in nearly all crops as they approached full maturity. In fact it became a reasonable indicator of crop maturity and readiness for harvest. There was no indication that black carrots were more susceptible than standard orange carrots in a wide range of project plantings.

- Black carrots are considerably more prone to forking than standard Red Hot (Apache) types. This appears to be related to air and soil temperatures rather than diseases like *Pythium*, unless extreme heat induces hypersensitivity to infection.

- Seedling "pinching" at the base also seems more likely to be a physiologically induced condition rather than a result of fungal infection.

- Nematodes do NOT appear to be the major cause of forking or other harvest deformities in black carrots in Australia.

<u>NB</u>: Some of the chemical products used in project trials are NOT currently registered for use in carrots in Australia. Always read the label before using any of the products mentioned.

Plant Emergence & Establishment

Materials & Methods (BC0904 – Clyde, Vic, 2009)

Location
This trial was located near Clyde (approx: 38° 09′ 05″ S, 145° 20′ 38″ E) inside a dedicated bay separate from commercial bunching vegetable crops (Dutch Carrots, Bok-Choy, Bunching onions etc), on very light sandy black soil, typical of the region.

Design
Treatments were replicated four times in randomised complete blocks. Plots consisted of two pair-planted rows (4 single rows in total) on a single bed 1.63 m wide (bed centre to adjacent bed centre), 0.50m length planted, with 0.25m buffer at each end (1.0m plot length).

Planting, Treatment & Establishment
Beds were formed several days before planting. Seed was weighed and treated as detailed in Table 9.1.2 prior to planting. All seed was planted on 05 Feb 2009, to a depth of about 5-10 mm by marking lines for rows, creating a shallow furrow with a vee-shaped aluminium tine. Exactly 100 seeds/plot were sprinkled down the furrows before being lightly covered by hand.

Fungicide treatments were applied on the same day to the soil, immediately after planting, using a trigger pump spray bottle to apply 125mL total water volume/0.5m plot. The spray was concentrated in a 10 cm wide band centred over individual seed lines, just avoiding overlap in adjacent paired rows. This gave a water volume of 1563L/ha (field) but this was effectively concentrated over only a quarter of this area (40cm of sprayed width/1.6m bed).

Irrigation
Irrigation was provided by solid set sprinklers arranged in a square grid pattern with 10 metres between risers. Irrigation intervals were determined by the grower and scheduled as for the rest of the farm, typically a single application of 6 mm/day at the beginning to 8-10 mm/day during the hottest parts of summer.

Nutrition
No base fertilizer was applied based on site history and soil nutrition history.

Maintenance
As this trial did not run for an extended period, no herbicides were applied (and fungicides were determined by treatments).

Assessments
Emergence (plants/plot) was measured 0, 2, 6, 8, 10, 15 & 21 days after planting. Any symptoms of phytotoxicity or differential plant vigour were noted if they occurred. Photos were also taken of key plots at key assessments.

<u>Statistical Analyses</u>:
In all tables shown, vertical bars aligned in the same column indicate means that are NOT SIGNIFICANTLY DIFFERENT (LSD, P=0.05). Means followed by "-" failed Bartlett's Chi-squared Test for Homogeneity of Variance and attempts to rectify this with transformations were NOT successful (P=0.05). NSAP indicates no statistical analysis performed. Blue vertical bars indicate LSD results based on successfully transformed data BUT the numbers they follow are original.

***Figure 9.1.1** – BC00904: Trial layout*

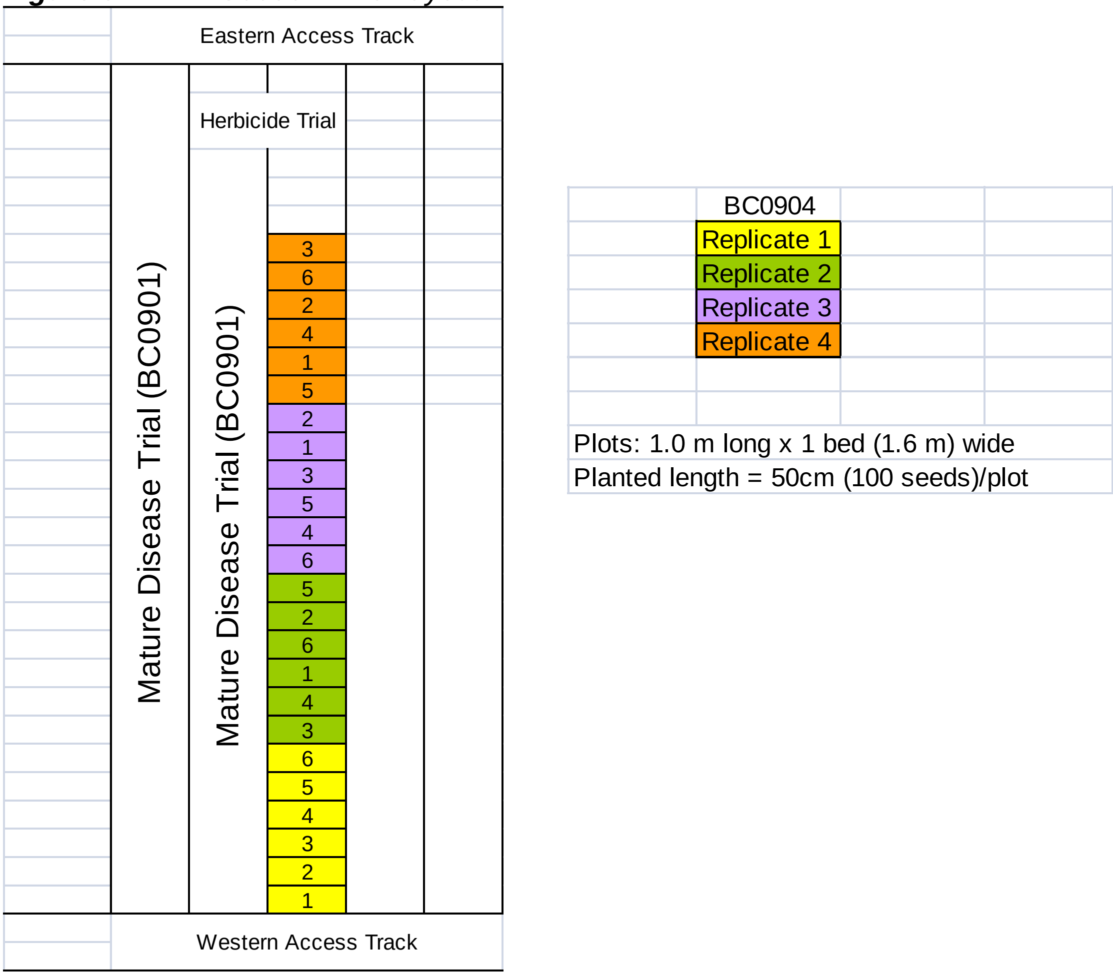


***Table 9.1.1** BC0904: Treatment Details (Seed & Soil Treatments)*

No.	Seed	Seed Treatment	Soil Treatment
1	LX3632	Nil	Nil
2	Apache	Thiram + Rovral + Apron XL 350 ES	Nil
3	LX3632	Apron XL 350 ES	Nil
4	LX3632	Apron XL 350 ES	Ridomil Gold 480 EC
5	LX3632	Maxim 100 FS + Apron XL 350 ES	Nil
6	LX3632	Maxim 100 FS + Apron XL 350 ES	Amistar 250 SC + Ridomil Gold 480 EC

Table 9.1.2 *BC0904: Seed Treatment Application Rates*

Product	Formulation Active Ingredient Concentration	Product Rate/kg seed	Active Ingredient Rate/kg seed	Total Application Volume (mL/kg seed)
Apron XL 350 ES	metalaxyl-m 350g/L	2.0mL	0.70g	100
Maxim 100 FS	azoxystrobin 100g/L	0.5mL	0.05g	100

Note: Treatments 5 & 6 had both fungicides combined and applied in the same water volume as treatments 3 & 4 (10mL/100g seed total volume).

Table 9.1.3 *BC0904: Soil Fungicide Application Rates*

Product	Formulation Active Ingredient Concentration	Product Rate/ha (field)	Active Ingredient Rate/ha (field)	Effective Product Rate/ha	Effective Active Ingredient Rate/ha
Ridomil Gold 480 EC	metalaxyl-m 480g/L	1250mL (0.10mL/ 0.125L/Plot)	600g	5000mL	2400g
Amistar 250 SC	azoxystrobin 250g/L	1563mL (0.125mL/ 0.125L/Plot)	391g	6252mL	1563g

Note: Treatment 5 had both fungicides combined and applied in the same water volume as treatments 3 & 4 (500mL water/plot).

Results & Discussion (BC0904 – Clyde, Vic, 2009)

Table 9.1.4 *BC0904: Plant Emergence (%) 0-21 days after planting, classified by seed, seed treatment and soil fungicide treatments applied.*

Treatment	Days After Planting						
	0	**2**	**6**	**8**	**10**	**15**	**21**
LX3632 (Untreated)	0 I	0 I	18 I	61 I	78 I I	79 I I I	80 I I I
Apache (Std ST)	0 I	0 I	0 I	5 I	66 I	84 I I	85 I I
LX3632 (met-m ST)	0 I	0 I	16 I I	66 I	85 I	88 I	87 I
LX3632 (met-m ST + met-m SD)	0 I	0 I	11 I I I	64 I	84 I	86 I I	86 I I
LX3632 (met-m ST + fdl ST)	0 I	0 I	10 I I	51 I	69 I I	70 I	71 I
LX3632 (met-m ST + fdl ST + azox SD + met-m SD)	0 I	0 I	8 I	48 I	71 I I	76 I I	77 I I

Notes: Std = Standard as supplied on seed; ST = Seed Treatment; SD = Soil Drench; met-m = metalaxyl-m; azox = azoxystrobin.

Figure 9.1.2 – *BC00904: Plant Emergence (%) 0-21 days after planting, classified by seed, seed treatment and soil fungicide treatments applied.*

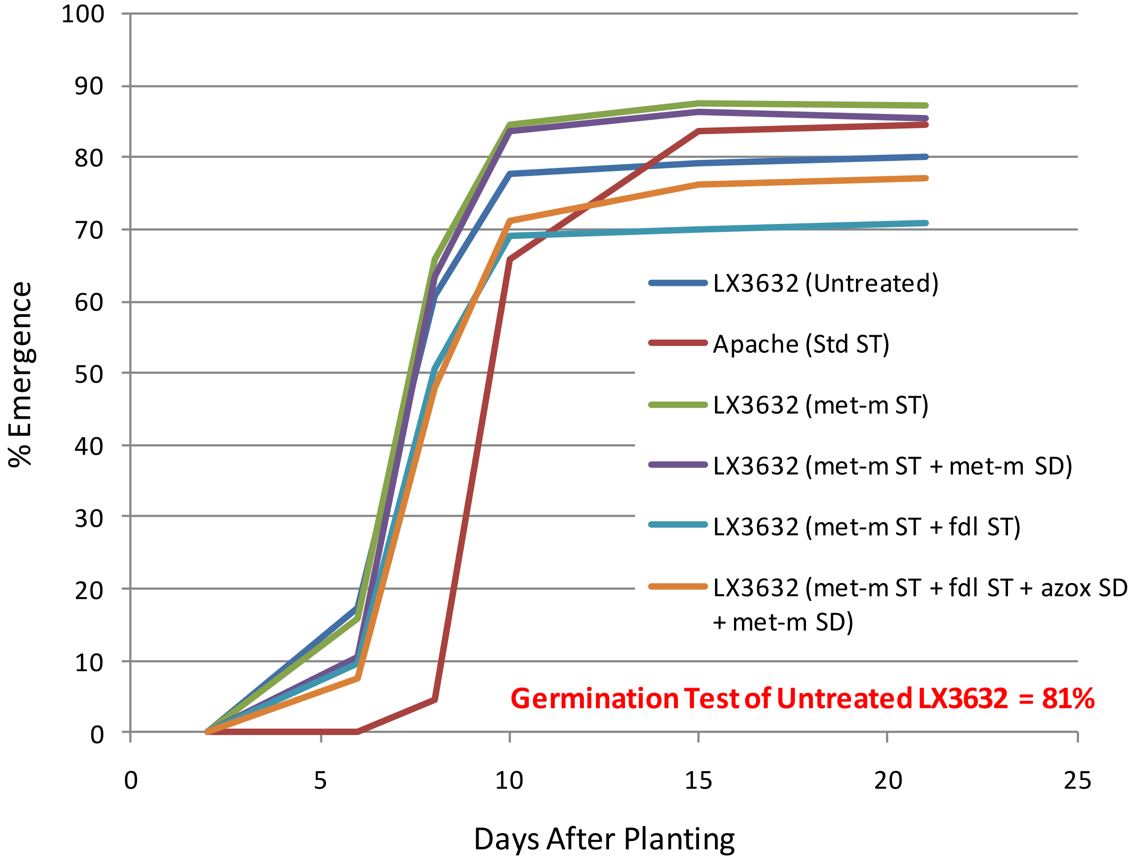
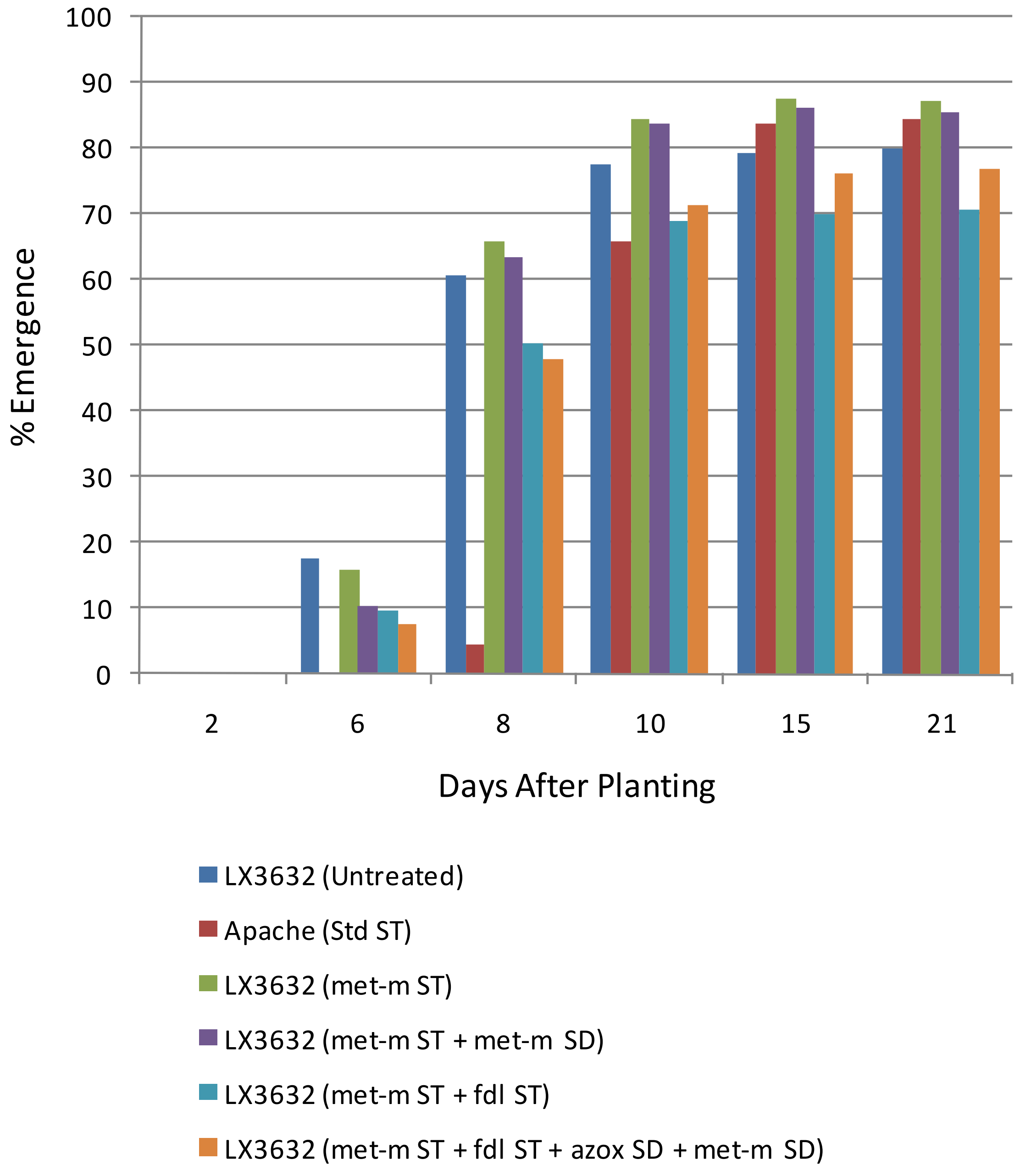


***Figure 9.1.3** – BC00904: Plant Emergence (%) 0-21 days after planting, classified by seed, seed treatment and soil fungicide treatments applied.*



There was no visual evidence of plant disease or lack of vigour in any treatment over the assessment period.

There was also no evidence that *Pythium spp., Fusarium spp., Rhizoctonia spp*. or *Alternaria spp.* significantly affected germination or plant establishment. Seed treatments and soil fungicide drenches provided no clear benefits to either the speed of emergence or to the ultimate level of emergence of LX3632. They also showed no clear signs of crop phytotoxicity. Untreated LX3632 gave 81% germination on cotton-wool at room temperature in the absence of soil disease, almost exactly the same figure as the same seed grown in the field.

Apache was significantly slower to emerge than LX3632.

Materials & Methods (BC0907 – Dareton, NSW, 2009)

Location
This trial was located at the NSW DPI Research Station near Dareton, NSW (approx: 34° 05′ 43″ S, 142° 00′ 53″ E, elevation 51 m) inside a dedicated area worked up managed solely for the purpose of conducting the trial, on a red loamy sand, typical of the region.

Design
Treatments were replicated four times in randomised complete blocks. Plots consisted of two pair-planted rows (4 single rows in total) on a single bed 1.63 m wide (bed centre to adjacent bed centre), 0.50m length planted, with 0.25m buffer at each end (1.0m plot length).

Planting, Treatment & Establishment
Beds were unformed but soil was cultivated just prior to planting. Seed was weighed and treated as detailed in Table 9.1.2 prior to planting. All seed was planted on 19 Feb 2009, to a depth of about 5-10 mm by marking lines for rows, creating a shallow furrow with a vee-shaped aluminium tine. Exactly 100 seeds/plot were sprinkled down the furrows before being lightly covered by hand.

Fungicide treatments were applied on the same day to the soil, immediately after planting, using a trigger pump spray bottle to apply 125mL total water volume/0.5m plot. The spray was concentrated in a 10 cm wide band centred over individual seed lines, just avoiding overlap in adjacent paired rows. This gave a water volume of 1563L/ha (field) but this was effectively concentrated over only a quarter of this area (40cm of sprayed width/1.6m bed).

Irrigation
Irrigation was provided by solid set sprinklers arranged in a square grid pattern with 10 metres between risers. Irrigation intervals were determined by the grower and scheduled as for the rest of the farm, typically a single application of 6 mm/day at the beginning to 8-10 mm/day during the hottest parts of summer.

Nutrition
No base fertilizer was applied based on site history and soil nutrition history.

Maintenance
As this trial did not run for an extended period, no herbicides were applied (and fungicides were determined by treatments).

Assessments
Emergence (plants/plot) was measured 22 days after planting (13 Mar 2009). Any symptoms of phytotoxicity or differential plant vigour were noted if they occurred. Photos were also taken of key plots at key assessments.

Statistical Analyses:
In all tables shown, vertical bars aligned in the same column indicate means that are NOT SIGNIFICANTLY DIFFERENT (LSD, P=0.05). Means followed by "-" failed Bartlett's Chi-squared Test for Homogeneity of Variance and attempts to rectify this with transformations were NOT successful (P=0.05). NSAP indicates no statistical analysis performed. Blue vertical bars indicate LSD results based on successfully transformed data BUT the numbers they follow are original.

Table 9.1.5 *BC0907: Treatment Details (Seed & Soil Treatments)*

No.	Seed	Seed Treatment	Soil Treatment
1	LX3632	Nil	Nil
2	Apache	Thiram + Rovral + Apron XL 350 ES	Nil
3	LX3632	Apron XL 350 ES	Nil
4	LX3632	Apron XL 350 ES	Amistar 250 SC + Ridomil Gold 480 EC

Table 9.1.6 *BC0907: Seed Treatment Application Rates*

Product	Formulation Active Ingredient Concentration	Product Rate/kg seed	Active Ingredient Rate/kg seed	Total Application Volume (mL/kg seed)
Apron XL 350 ES	metalaxyl-m 350g/L	2.0mL	0.70g	100
Maxim 100 FS	azoxystrobin 100g/L	0.5mL	0.05g	100

Note: Treatments 5 & 6 had both fungicides combined and applied in the same water volume as treatments 3 & 4 (10mL/100g seed total volume).

Table 9.1.7 *BC0907: Soil Fungicide Application Rates*

Product	Formulation Active Ingredient Concentration	Product Rate/ha (field)	Active Ingredient Rate/ha (field)	Effective Product Rate/ha	Effective Active Ingredient Rate/ha
Ridomil Gold 480 EC	metalaxyl-m 480g/L	625mL (0.05mL/ 0.125L/Plot)	300g	2500mL	1200g
Amistar 250 SC	azoxystrobin 250g/L	1563mL (0.125mL/ 0.125L/Plot)	391g	6252mL	1563g

Note: Treatment 5 had both fungicides combined and applied in the same water volume as treatments 3 & 4 (500mL water/plot).

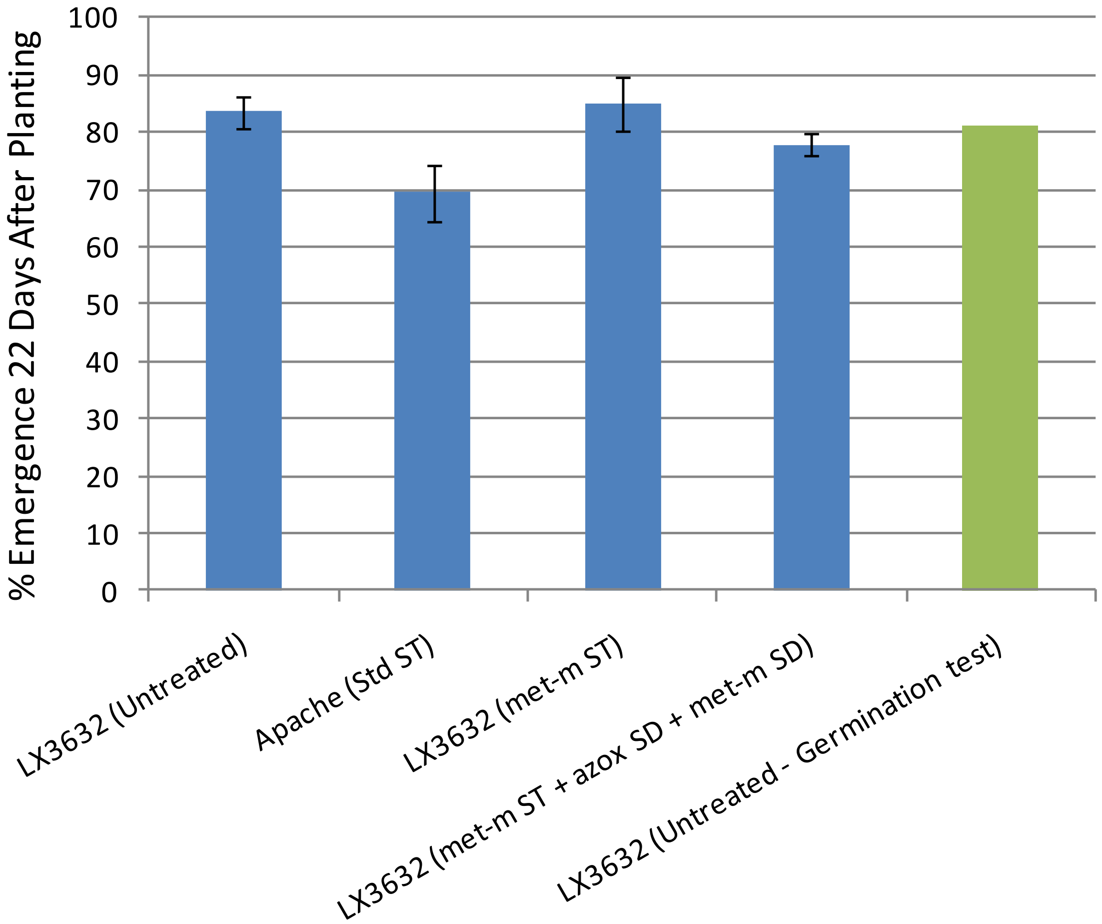
Results & Discussion (BC0907 – Dareton, NSW, 2009)

Table 9.1.8 *BC0907: Plant Emergence (%) 22 days after planting, classified by seed, seed treatment and soil fungicide treatments applied.*

Treatment	Days After Planting	
	0	22
LX3632 (Untreated)	0 I	84 I
Apache (Std ST)	0 I	70 I
LX3632 (met-m ST)	0 I	85 I
LX3632 (met-m ST + azox SD + met-m SD)	0 I	78 I

Notes: Std = Standard as supplied on seed; ST = Seed Treatment; SD = Soil Drench; met-m = metalaxyl-m; azox = azoxystrobin.

Figure 9.1.4 *– BC00907: Plant Emergence (%) 22 days after planting, classified by seed, seed treatment and soil fungicide treatments applied.*



There was no visual evidence of plant disease or lack of vigour in any treatment.

There was also no evidence that *Pythium spp., Fusarium spp., Rhizoctonia spp*. or *Alternaria spp.* significantly affected germination or plant establishment. Seed treatments and soil fungicide drenches provided no clear benefits to the final level of emergence of LX3632. They also showed no clear signs of crop phytotoxicity. Untreated LX3632 gave 81% germination on cotton-wool at room temperature in the absence of soil disease, almost exactly the same figure as the same seed grown in the field.

Apache showed a slightly (but not significantly) lower level of emergence.

Materials & Methods (BC0908 – Parilla, SA, 2009)

Location
This trial was located at the Parilla Premium Potatoes, Parilla, SA (approx: 35° 17′ 42″ S, 140° 42′ 38″ E), on a carrot/onion/potato rotational, yellow sand, typical of the region.

Design
Treatments were replicated four times in randomised complete blocks. Plots consisted of two pair-planted rows (4 single rows in total) on a single bed 1.63 m wide (bed centre to adjacent bed centre), 0.50m length planted, with 0.25m buffer at each end (1.0m plot length).

Planting, Treatment & Establishment
Beds were unformed but soil was cultivated just prior to planting. Seed was weighed and treated as detailed in Table 9.1.2 prior to planting. All seed was planted on 18 Feb 2009, to a depth of about 5-10 mm by marking lines for rows, creating a shallow furrow with a vee-shaped aluminium tine. Exactly 100 seeds/plot were sprinkled down the furrows before being lightly covered by hand.

Fungicide treatments were applied on the same day to the soil, immediately after planting, using a trigger pump spray bottle to apply 125mL total water volume/0.5m plot. The spray was concentrated in a 10 cm wide band centred over individual seed lines, just avoiding overlap in adjacent paired rows. This gave a water volume of 1563L/ha (field) but this was effectively concentrated over only a quarter of this area (40cm of sprayed width/1.6m bed).

Irrigation
Irrigation was provided by centre-pivot. Irrigation intervals were determined by the grower and scheduled as for the rest of the farm, typically a single application of 8-10 mm/day over the duration of this trial.

Nutrition
No base fertilizer was applied based on site history and soil nutrition history.

Maintenance
As this trial did not run for an extended period, no herbicides were applied (and fungicides were determined by treatments).

Assessments
Emergence (plants/plot) was measured 22 days after planting (12 Mar 2009). Any symptoms of phytotoxicity or differential plant vigour were noted if they occurred. Photos were also taken of key plots at key assessments.

Statistical Analyses:
In all tables shown, vertical bars aligned in the same column indicate means that are NOT SIGNIFICANTLY DIFFERENT (LSD, P=0.05). Means followed by "-" failed Bartlett's Chi-squared Test for Homogeneity of Variance and attempts to rectify this with transformations were NOT successful (P=0.05). NSAP indicates no statistical analysis performed. Blue vertical bars indicate LSD results based on successfully transformed data BUT the numbers they follow are original.

Table 9.1.9 *BC0908: Treatment Details (Seed & Soil Treatments)*

No.	Seed	Seed Treatment	Soil Treatment
1	LX3632	Nil	Nil
2	Apache	Thiram + Rovral + Apron XL 350 ES	Nil
3	LX3632	Apron XL 350 ES	Nil
4	LX3632	Apron XL 350 ES	Amistar 250 SC + Ridomil Gold 480 EC

Table 9.1.10 *BC0908: Seed Treatment Application Rates*

Product	Formulation Active Ingredient Concentration	Product Rate/kg seed	Active Ingredient Rate/kg seed	Total Application Volume (mL/kg seed)
Apron XL 350 ES	metalaxyl-m 350g/L	2.0mL	0.70g	100
Maxim 100 FS	azoxystrobin 100g/L	0.5mL	0.05g	100

Note: Treatments 5 & 6 had both fungicides combined and applied in the same water volume as treatments 3 & 4 (10mL/100g seed total volume).

Table 9.1.11 *BC0908: Soil Fungicide Application Rates*

Product	Formulation Active Ingredient Concentration	Product Rate/ha (field)	Active Ingredient Rate/ha (field)	Effective Product Rate/ha	Effective Active Ingredient Rate/ha
Ridomil Gold 480 EC	metalaxyl-m 480g/L	625mL (0.05mL/ 0.125L/Plot)	300g	2500mL	1200g
Amistar 250 SC	azoxystrobin 250g/L	1563mL (0.125mL/ 0.125L/Plot)	391g	6252mL	1563g

Note: Treatment 5 had both fungicides combined and applied in the same water volume as treatments 3 & 4 (500mL water/plot).

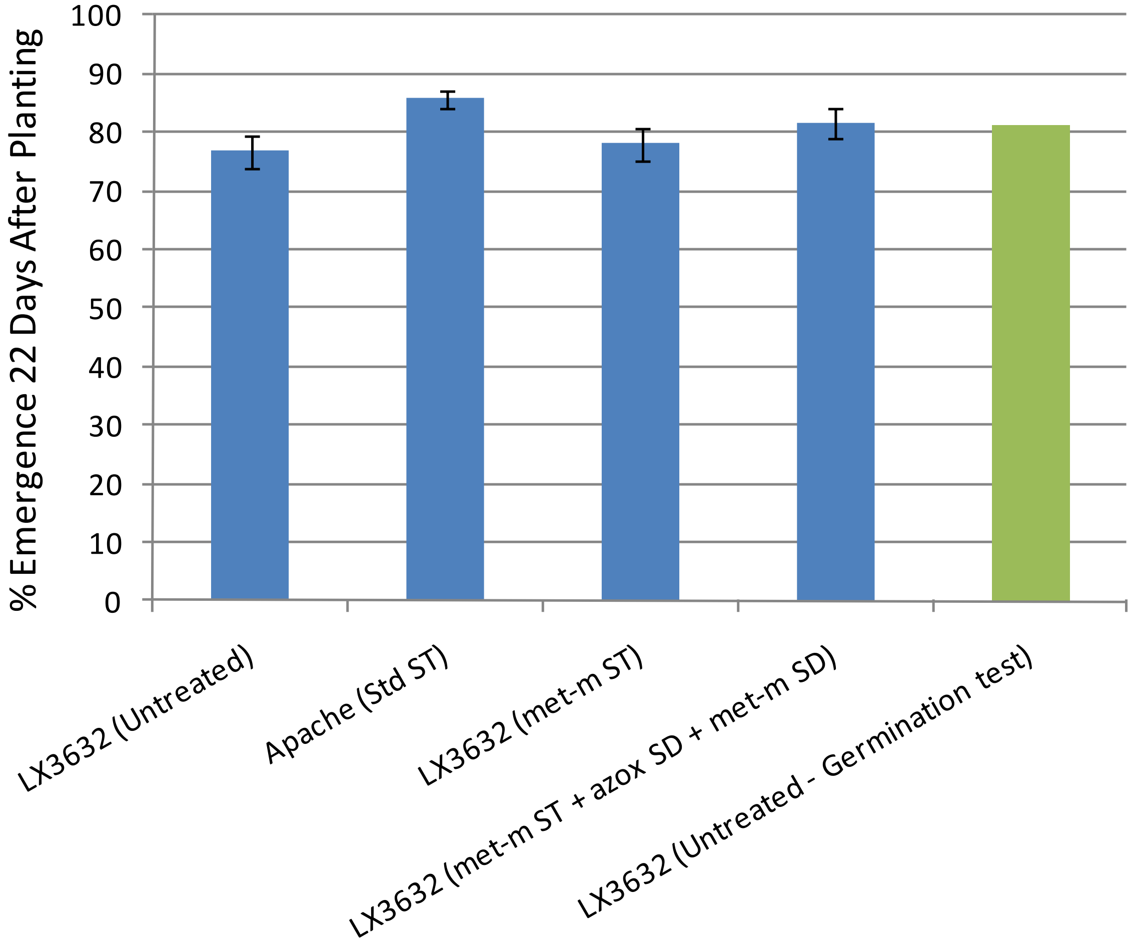
Results & Discussion (BC0908 – Parilla, SA, 2009)

Table 9.1.12 *BC0908: Plant Emergence (%) 22 days after planting, classified by seed, seed treatment and soil fungicide treatments applied.*

Treatment	Days After Planting	
	0	**22**
LX3632 (Untreated)	0 I	77 I
Apache (Std ST)	0 I	86 I
LX3632 (met-m ST)	0 I	78 I
LX3632 (met-m ST + azox SD + met-m SD)	0 I	82 I

Notes: Std = Standard as supplied on seed; ST = Seed Treatment; SD = Soil Drench; met-m = metalaxyl-m; azox = azoxystrobin.

Figure 9.1.5 *– BC00908: Plant Emergence (%) 22 days after planting, classified by seed, seed treatment and soil fungicide treatments applied.*



There was no visual evidence of plant disease or lack of vigour in any treatment.

There was also no evidence that *Pythium spp., Fusarium spp., Rhizoctonia spp*. or *Alternaria spp.* significantly affected germination or plant establishment. Seed treatments and soil fungicide drenches provided no clear benefits to the final level of emergence of LX3632. They also showed no clear signs of crop phytotoxicity. Untreated LX3632 gave 81% germination on cotton-wool at room temperature in the absence of soil disease, almost exactly the same figure as the same seed grown in the field.

Apache showed a slightly (but not significantly) lower level of emergence.

Effects of Soil-borne Diseases on Harvest Quality & Yield

Materials & Methods (BC0901 – Clyde, Vic, 2009)

Location:

This trial was located near Clyde (approx: 38° 09′ 05″ S, 145° 20′ 38″ E) inside a dedicated bay separate from commercial bunching vegetable crops (Dutch Carrots, Bok-Choy, Bunching onions etc), on very light sandy black soil, typical of the region.

Design:

Treatments were replicated four times in randomised complete blocks. Plots consisted of two pair-planted rows (4 single rows in total) on a single bed 1.63 m wide (bed centre to adjacent bed centre), 2.0 metres long.

Planting, Treatment & Establishment

Beds were formed several days before planting. The first attempt at sowing was made on 15 Jan 2009. All seed was hand sown, to a depth of about 5-10 mm by marking lines for rows, creating a shallow furrow with a vee-shaped aluminium tine. Plots were then seeded by hand, by pouring seed into furrows at approximately 4 times the standard seeding rate for later hand thinning. Furrows were then lightly covered by hand.

Fungicide treatments were applied 16 Jan 2009, to the soil using a trigger pump spray bottle to apply 500mL total water volume/2.0m plot. The spray was concentrated in a 10 cm wide band centred over individual seed lines, just avoiding overlap in adjacent paired rows. This gave a water volume of 1563L/ha (field) but this was effectively concentrated over only a quarter of this area (40cm of sprayed width/1.6m bed). Treatments were reapplied 26 Feb 2009 & 8 May 2009.

On 16 Jan 2009, immediately after soil fungicide treatments were applied, Linuron 500 WG + Gesagard 500 SC applied at 2.2kg/ha + 1.1L/ha respectively (Single jet, flat-fan knapsack sprayer at 250L/ha output).

Very poor emergence and dead emerged seedlings was noted on 02 Feb 2009 (18 days after planting). The trial area was sprayed with glyphosate to kill any emerged plants and resown 03 Feb 2009. Severely hot weather during the critical emergence period led to hand watering every 2nd hour (1mm/application) on 07 Feb 2009 ("Black Saturday"). This second planting emerged well and was thinned 13 & 15 March 2009.

Irrigation

Irrigation was provided by solid set sprinklers arranged in a square grid pattern with 10 metres between risers. Irrigation intervals were determined by the grower and scheduled as for the rest of the farm, typically a single application of 6 mm/day at the beginning to 8-10 mm/day during the hottest parts of summer.

Nutrition

No base fertilizer was applied based on site history and soil nutrition history. Hortico Aquasol™ applied at 4.0 g/m^2 on 10 Mar & 2.0 g/m^2 28 May 2009. A leaf sample collected 16 Jun 2009 showed trace and minor element deficiencies (Ca, Mg, Bo, Cu, Fe, Mg & Mo). Gypsum was applied at 1.0 kg/m^2 along with Hortico Aquasol™ at 2.0 g/m^2 on 25 Jun 2009.

Table 9.1.13 *BC0901: Treatment Details (seed, seed treatment and soil fungicide treatments applied)*

No.	Seed	16 Jan 2009 (18 Days Before Planting)	26 Feb 2009 (23 Days After Planting)	8 May 2009 (94 Days After Planting)
1	Red Hot			
2	LX3632			
3	LX3632	Ridomil Gold 480 EC	Ridomil Gold 480 EC	Ridomil Gold 480 EC
4	LX3632	Amistar 250 SC	Amistar 250 SC	Amistar 250 SC
5	LX3632	Ridomil Gold 480 EC + Amistar 250 SC	Ridomil Gold 480 EC + Amistar 250 SC	Ridomil Gold 480 EC + Amistar 250 SC

The original intention was to apply fungicides on the day of planting, then at 6, 12 & 18 weeks. However, replanting meant the first application was already in place when the site was re-established. Three applications with the final one at 94 days was deemed adequate in conjunction with the high product use rates to ensure results if significant disease pressure occurred.

Table 9.1.14 *BC0901: Product Application Rates/Application*

Product	Formulation Active Ingredient Concentration	Product Rate/ha (field)	Active Ingredient Rate/ha (field)	Effective Product Rate/ha	Effective Active Ingredient Rate/ha
Ridomil Gold 480 EC	metalaxyl-m 480g/L	781mL (0.25mL/ 0.5L/Plot)	375g	3124mL	1500g
Amistar 250 SC	azoxystrobin 250g/L	1563mL (0.50mL/ 0.5L/Plot)	391g	6252mL	1563g

Note: Treatment 5 had both fungicides combined and applied in the same water volume as treatments 3 & 4 (500mL water/plot).

Evaluation:
Photographs were taken at various stages between emergence and harvest. Poorly emerging and unhealthy plants were photographed soon after emergence and sent off for pathological examination at the Waite Institute, SARDI, SA. Foliar samples using 10 x YML (youngest mature leaf) were taken from selected plots at late maturity and harvest for complete dry-ash analysis (Phosyn Analytical). Harvest was carried out on 28-29 Jul 2009, (175 DAP) by harvesting 1.00m of bed (all 4 carrot rows). Over following two days samples were assessed for disease, bolting, carrot numbers, weights, shapes, cracking, deformities or other anomalies. After taking photographs of whole samples, entire plot yields were packed in plastic bags and cool stored. They were cool stored for up to several weeks at 4° C, before being juiced at SDS Beverages in Merbein, with whole replicates taken and juiced the same day. A 500 mL sample of juice was kept from each sample, frozen and subsequently analysed in SDS's Merbein laboratory for Brix using a refractometer and anthocyanin content using an absorbance spectrophotometer.

Statistical Analyses:
In all tables shown, vertical bars aligned in the same column indicate means that are NOT SIGNIFICANTLY DIFFERENT (LSD, P=0.05). Means followed by "-" failed Bartlett's Chi-squared Test for Homogeneity of Variance and attempts to rectify this with transformations were NOT successful (P=0.05). NSAP indicates no statistical analysis performed. Blue vertical bars indicate LSD results based on successfully transformed data BUT the numbers they follow are original.

Results (BC0901 – Clyde, Vic, 2009)

Table 9.1.15 *BC0901: Carrot Yield Components – Total & Harvestable Yields (t/ha), classified by seed and soil fungicide treatments applied*

Treatment	TOTAL Yield (t/ha)	Treatment	YIELD 21+mm (t/ha)	Treatment	YIELD 26+mm (t/ha)
Red Hot (Standard)	60.148 I	Red Hot (Standard)	59.375 I	Red Hot (Standard)	54.244 I
Black (met-m + azoxy)	37.472 I	Black (met-m + azoxy)	36.581 I	Black (met-m + azoxy)	34.327 I
Black (Untreated)	35.095 I	Black (Untreated)	34.267 I	Black (Untreated)	32.173 I
Black (azoxy)	33.070 I	Black (azoxy)	32.259 I	Black (azoxy)	30.172 I
Black (met-m)	32.150 I	Black (met-m)	31.352 I	Black (met-m)	29.498 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Table 9.1.16 *BC0901: Carrot Yield Components – Total & Harvestable Yields (Numbers of Carrots), classified by seed and soil fungicide treatments applied*

Treatment	TOTAL No./ha	Treatment	No. 21+mm/ha	Treatment	No. 26+mm/ha
Red Hot (Standard)	784375 I	Red Hot (Standard)	721875 I	Red Hot (Standard)	585938 I
Black (met-m + azoxy)	678125 I	Black (met-m + azoxy)	551563 I	Black (met-m + azoxy)	443750 I
Black (azoxy)	656250 I	Black (azoxy)	526563 I	Black (azoxy)	412500 I
Black (met-m)	615625 I	Black (Untreated)	501563 I	Black (Untreated)	396875 I
Black (Untreated)	609375 I	Black (met-m)	492188 I	Black (met-m)	395313 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Table 9.1.17 *BC0901: Carrot Yield Components – Undersize Yields (t/ha), classified by seed and soil fungicide treatments applied*

Treatment	YIELD <21mm (t/ha)	Treatment	YIELD 21-25mm (t/ha)
Black (met-m + azoxy)	0.891 I	Red Hot (Standard)	5.131 I
Black (Untreated)	0.828 I	Black (met-m + azoxy)	2.255 I
Black (azoxy)	0.811 I	Black (Untreated)	2.094 I
Black (met-m)	0.798 I	Black (azoxy)	2.088 I
Red Hot (Standard)	0.773 I	Black (met-m)	1.853 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Table 9.1.18 *BC0901: Carrot Yield Components – Undersize Yields (Numbers of Carrots), classified by seed and soil fungicide treatments applied*

Treatment	No. <21mm	Treatment	No. 21-25mm
Black (azoxy)	129688 I	**Red Hot (Standard)**	135938 I
Black (met-m + azoxy)	126563 I	**Black (azoxy)**	114063 I
Black (met-m)	123438 I	**Black (met-m + azoxy)**	107813 I
Black (Untreated)	107813 I	**Black (Untreated)**	104688 I
Red Hot (Standard)	62500 I	**Black (met-m)**	96875 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Figure 9.1.6 *– BC00901: Total Carrot Yield and Yield Components (t/ha), classified by seed and soil fungicide treatments applied*

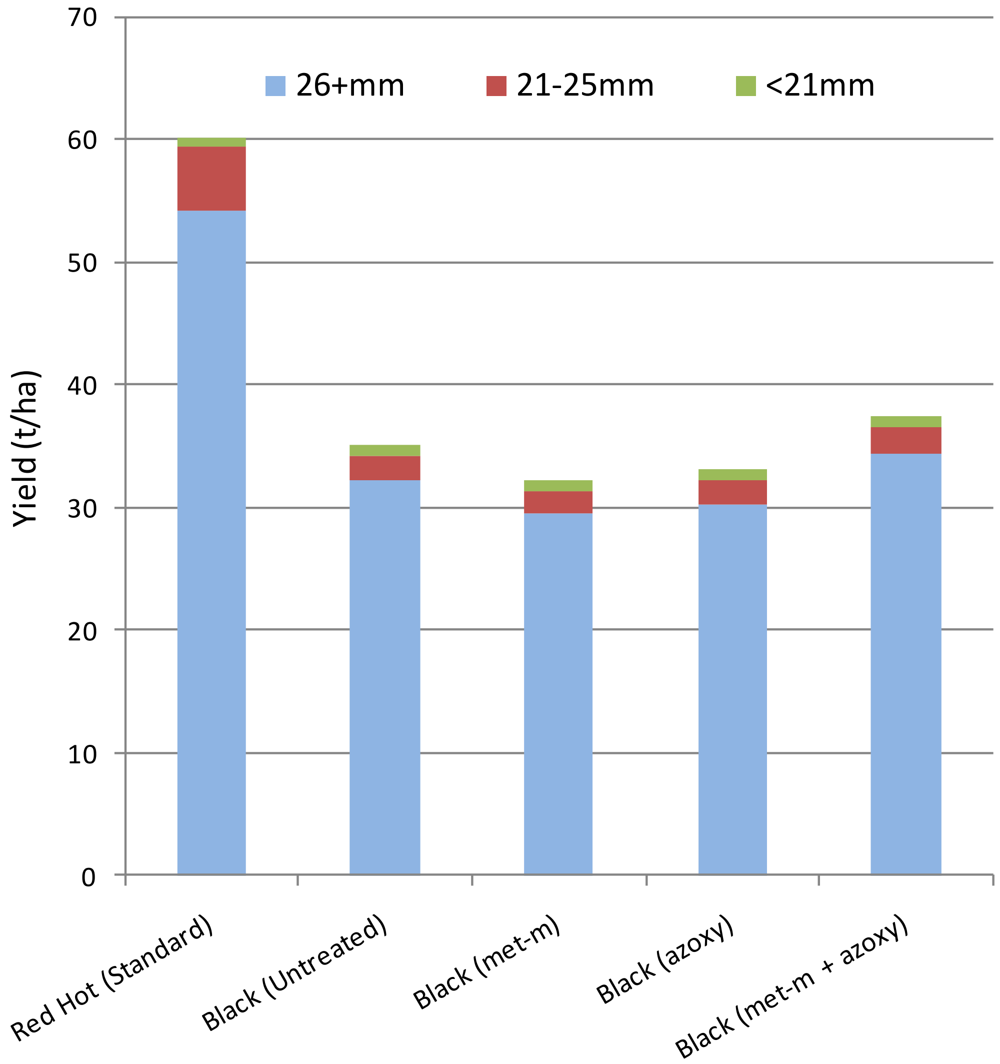


Figure 9.1.7 *– BC00901: Total Yield (t/ha) - Forked & Straight (Unforked), classified by seed and soil fungicide treatments applied*

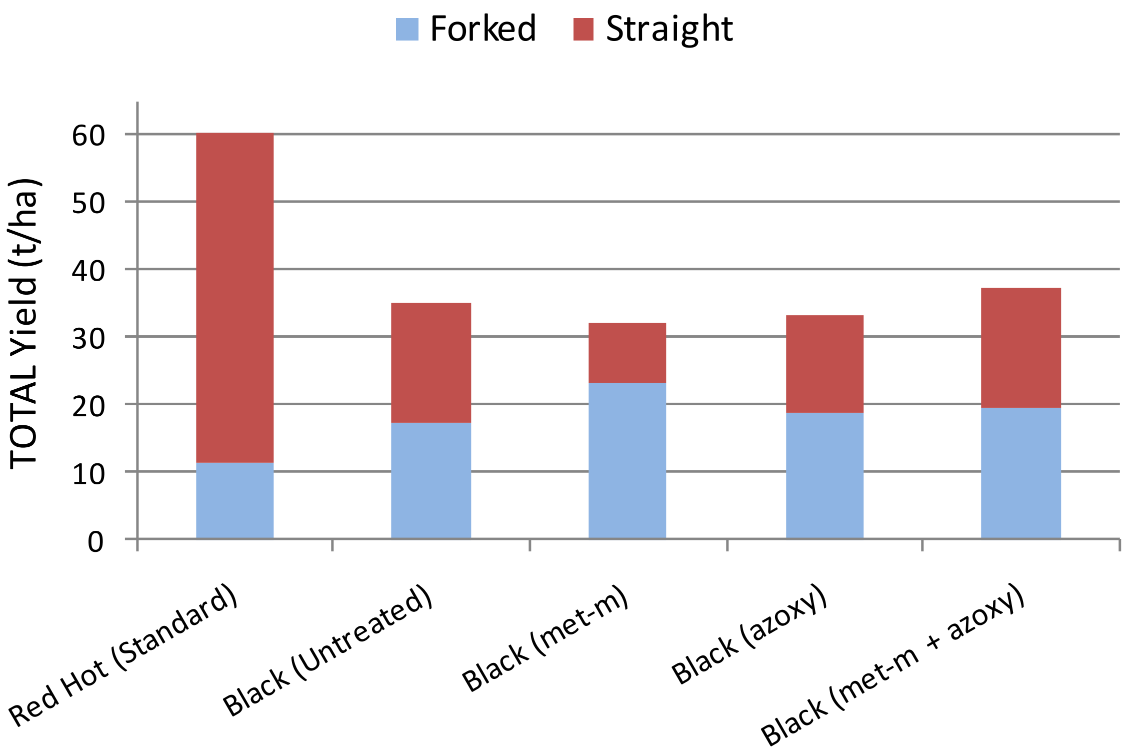


Figure 9.1.8 *– BC00901: Proportion (%) of Total Yield - Forked & Straight (Unforked), classified by seed and soil fungicide treatments applied*

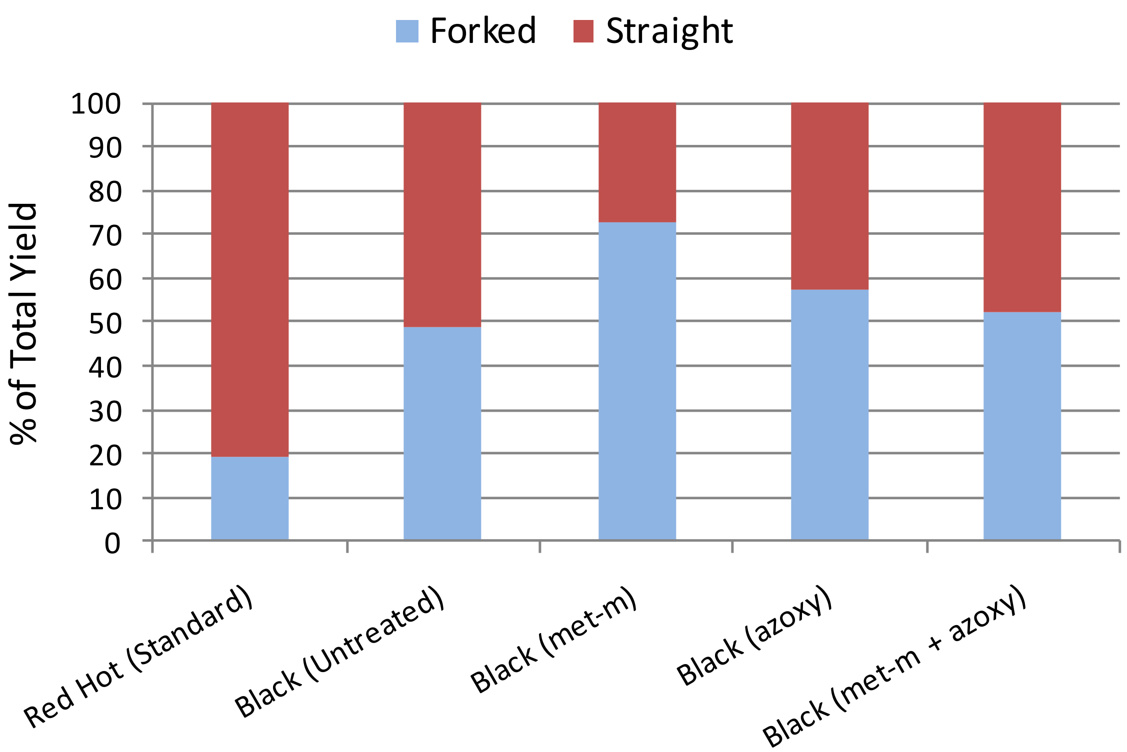


Table 9.1.19 *BC0901:* ***Forked*** *Yield Components – Total & Harvestable Forked Yields (t/ha), classified by seed and soil fungicide treatments applied*

Treatment	TOTAL Forked Yield (t/ha)	Treatment	Forked YIELD 21+mm (t/ha)	Treatment	Forked YIELD 26+mm (t/ha)
Black (met-m)	23.350 I	**Black (met-m)**	23.070 I	**Black (met-m)**	22.063 I
Black (met-m + azoxy)	19.672 I	**Black (met-m + azoxy)**	19.514 I	**Black (met-m + azoxy)**	19.000 I
Black (azoxy)	18.947 I	**Black (azoxy)**	18.678 I	**Black (azoxy)**	17.961 I
Black (Untreated)	17.167 I	**Black (Untreated)**	16.908 I	**Black (Untreated)**	16.367 I
Red Hot (Standard)	11.452 I	**Red Hot (Standard)**	11.286 I	**Red Hot (Standard)**	10.973 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Table 9.1.20 *BC0901:* ***Forked*** *Yield Components – Total & Harvestable Forked Yields (Numbers of Carrots), classified by seed and soil fungicide treatments applied*

Treatment	TOTAL Forked No./ha	Treatment	Forked No. 21+mm/ha	Treatment	Forked No. 26+mm/ha
Black (met-m)	398438 I	**Black (met-m)**	346875 I	**Black (met-m)**	287500 I
Black (azoxy)	339063 I	**Black (azoxy)**	289063 I	**Black (azoxy)**	235938 I
Black (met-m + azoxy)	300000 I	**Black (met-m + azoxy)**	267188 I	**Black (met-m + azoxy)**	229688 I
Black (Untreated)	268750 I	**Black (Untreated)**	234375 I	**Black (Untreated)**	198438 I
Red Hot (Standard)	146875 I	**Red Hot (Standard)**	126563 I	**Red Hot (Standard)**	109375 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Table 9.1.21 *BC0901:* ***Forked*** *Carrot Yield Components – Undersize Forked Yields (t/ha), classified by seed and soil fungicide treatments applied*

Treatment	Forked YIELD <21mm (t/ha)	Treatment	Forked YIELD 21-25mm (t/ha)
Black (met-m)	0.280 I	**Black (met-m)**	1.008 I
Black (azoxy)	0.269 I	**Black (azoxy)**	0.717 I I
Black (Untreated)	0.259 I	**Black (Untreated)**	0.541 I I
Red Hot (Standard)	0.166 I	**Black (met-m + azoxy)**	0.514 I I
Black (met-m + azoxy)	0.158 I	**Red Hot (Standard)**	0.313 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Table 9.1.22 *BC0901:* ***Forked*** *Carrot Yield Components – Undersize Yields (Numbers of Carrots), classified by seed and soil fungicide treatments applied*

Treatment	Forked No. <21mm	Treatment	Forked No. 21-25mm
Black (met-m)	51563 I	Black (met-m)	59375 I
Black (azoxy)	50000 I	Black (azoxy)	53125 I
Black (Untreated)	34375 I	Black (met-m + azoxy)	37500 I
Black (met-m + azoxy)	32813 I	Black (Untreated)	35938 I
Red Hot (Standard)	20313 I	Red Hot (Standard)	17188 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Table 9.1.23 *BC0901: Av. Carrot Weights (g) based on Total & Harvestable Carrot Weights (g), classified by seed and soil fungicide treatments applied*

Treatment	Av. Carrot Weight – All Sizes (g)	Treatment	Av. Carrot Weight – 21+mm Yield (g)	Treatment	Av. Carrot Weight – 26+mm Yield (g)
Red Hot (Standard)	77 I	Red Hot (Standard)	82 I	Red Hot (Standard)	93 I
Black (Untreated)	58 I	Black (Untreated)	69 I	Black (Untreated)	81 I I
Black (met-m + azoxy)	56 I	Black (met-m + azoxy)	67 I	Black (met-m + azoxy)	78 I
Black (met-m)	53 I	Black (met-m)	64 I	Black (met-m)	75 I
Black (azoxy)	51 I	Black (azoxy)	61 I	Black (azoxy)	73 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Table 9.1.24 *BC0901: Canopy Yield (t/ha) & Canopy/Carrot Ratio, classified by seed and soil fungicide treatments applied*

Treatment	Canopy Yield (t/ha)	Treatment	Canopy/ Carrot Weight Ratio
Black (met-m + azoxy)	25.864 I	Red Hot (Standard)	0.2812 I
Black (met-m)	24.100 I	Black (azoxy)	0.6143 I
Black (Untreated)	21.839 I I	Black (Untreated)	0.6300 I
Black (azoxy)	20.495 I I	Black (met-m + azoxy)	0.6902 I
Red Hot (Standard)	16.856 I	Black (met-m)	0.7458 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Table 9.1.25 *BC0901: Brix (°Br) & pH, classified by seed and soil fungicide treatments applied*

Treatment	Brix (°Br)	Treatment	pH
Black (met-m)	11.0 I	**Black (met-m + azoxy)**	6.19 I
Black (met-m + azoxy)	10.9 I	**Black (azoxy)**	6.18 I
Black (azoxy)	10.7 I	**Black (met-m)**	6.15 I
Black (Untreated)	10.5 I	**Red Hot (Standard)**	6.14 I
Red Hot (Standard)	10.1 I	**Black (Untreated)**	6.12 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Table 9.1.26 *BC0901: Absorbance (@538nm) & Anthocyanins (mg%@8.0°Br), classified by seed and soil fungicide treatments applied*

Treatment	Absorbance (@538nm)	Treatment	Anthocyanins (mg%@8.0°Br)
Black (azoxy)	0.811 I	**Black (azoxy)**	83.3 I
Black (met-m + azoxy)	0.788 I	**Black (met-m + azoxy)**	81.1 I
Black (met-m)	0.668 I	**Black (met-m)**	68.6 I
Black (Untreated)	0.665 I	**Black (Untreated)**	68.3 I

Notes: Standard = As supplied on seed; met-m = metalaxyl-m; azoxy = azoxystrobin.

Discussion (BC0901 – Clyde, Vic, 2009)

Superficial skin blemishes caused by cavity spot (*Pythium spp,*) were fairly common in the standard Red Hot carrots but nearly impossible to see on black carrots, regardless of the treatment. While it is a major problem in fresh production and was a widespread problem at this site, it is of little consequence in processing carrots for juice, whether they are peeled or not. Given the difficulty seeing these blemishes on black carrots, it is unlikely to be of great importance even if a fresh market is established for them, at least compared with current orange varieties.

Early diagnosis of weak, stressed seedlings showing severe “pinching” at the base, failed to show any suspicious fungal pathogens. The cause of this is believed to be heat related and dealt with in Section 9.2.

At harvest, no typical carrot disease symptoms were widespread in the trial or in any particular treatment. Some isolated, concentrated and minor infections of *Rhizoctonia* were found in association with deeper cavity spot lesions, but too few too make reasonable numerical comparisons. This is consistent with the findings of Davison & McKay (1998), who reported *Rhizoctonia* and *Fusarium* were considered secondary not primary colonizers.

The most important factors that could be assessed were any affects on yield, sizes and quality, in particular forking. *Pythium* is often credited as being one of the key causes of forking. Davison & McKay (2003) for example, found reduced seedling infection was associated with a decrease in forking. There was little evidence this was the case in this trial.

Reduced persistence of metalaxyl-m has been observed in Western Australia (Davison & McKay, 1999). The half-life, was found to have been reduced from about 82 days to 10. *Pythium* populations isolated from these soils still showed full sensitivity to the fungicide. This indicated enhanced [microbial] breakdown of metalaxyl-m. This situation was anticipated when the trial was designed, by using high rates and multiple applications of metalaxyl-m and using another *Pythium* active fungicide (azoxystrobin), again at high rates with multiple applications. Even allowing for degradation and a reduced population sensitivity to metalaxyl-m, at least some of the fungicide treatments should have shown at least some reductions in forking, had *Pythium* been associated with this condition.

Another key reason for questioning the role *Pythium* may play in causing forking was the much lower frequency (5-8%) seen in a density trial planted in a bed immediately next to this one (Trial BC0905 - Table 4.15), only 9 days later.

Total & Harvestable Yields by Weight (Table 9.1.15)
There were no significant total or harvestable yield differences associated with the fungicide treatments applied. This was true whether total yield or harvestable yield based on a 21mm or 26mm minimum shoulder width were imposed. Red Hot in the absence of any added fungicide protection yielded significantly better (up to 90% more) than any black carrot treatment, whether total or harvestable yields were compared.

Total & Harvestable Yields by Number (Table 9.1.16)
Bearing in mind these carrots were hand-thinned to similar densities, no differences in total or harvestable yields based on numbers of carrots were significant. Red Hot produced more harvestable sized carrots than any black carrot treatment but the difference was not significant.

Undersize Yields by Weight (Table 9.1.17) & Number (Table 9.1.18)
The yields of carrots <21mm was not significantly different for any treatment, but Red Hot showed a significantly greater yield of 21-25mm diameter carrots by weight.

Yield – All Components Summed by Weight (Figure 9.1.16)
This figure shows that yields of carrots <26mm only accounted for about 5% of black carrot yield but around 10% of total Red Hot yields (mostly from the higher 21-25mm yield).

Forked Yields by Weight & Number (Tables 9.1.19-9.1.22 & Figures 9.1.7 & 9.1.8)
There were no reductions in forked yields that resulted from the use of different fungicide treatments. Yields of forked carrots from different treatments remained proportional across the different size categories. This was true for both weights and numbers of carrots. Red Hot showed lower yields of forked carrots in all size grades, but not significantly so. However, in percentage terms, forked carrots were less than 20% of total Red Hot yield, whereas forked carrots represented around 50-70% of black carrot yields. Black carrots receiving no fungicide protection showed the same level of forking as a proportion of total yield as those that did.

All of these factors make it unlikely that soil-borne disease was the primary cause of the forking seen in this trial.

Canopy Yields & Canopy/Carrot Weight Ratios (Table 9.1.24)
There was little difference in canopy weight among the black carrot treatments or the canopy/carrot weight ratio. Red Hot had the lowest canopy yield and a significantly lower canopy/carrot weight ratio.

Brix, pH, Absorbance & Anthocyanin Content (Table 9.1.25 & 9.1.26)
There were no significant treatment differences and no discernable trends associated with fungicide treatments for any of these parameters. Brix levels were good and anthocyanin levels were fair to good.

Bolting
There was no early bolting but by 175 days after planting and sufficient winter cold, plants were beginning to bolt. This was the trigger for harvest but no yield adjustments were required to account for this factor.

Nutrient Use & Removal
Foliar and carrot nutrient analysis from this trial was used to calculate approximate nutrient removal by the crop (Section 5).

Materials & Methods (BC0903 – Dareton, NSW, 2010)

This trial was initiated but uneven germination, unrelated to treatments resulted in the trial being discontinued. While no formal assessments were made, it was clear that disease levels were insignificant and no clear differences in carrots from the two treatments were apparent when the trial was abandoned on 01 May 2010.

Location
This trial was located at the NSW DPI Research Station near Dareton, NSW (approx: 34° 05′ 43″ S, 142° 00′ 53″ E, elevation 51 m) inside a dedicated area worked up managed solely for the purpose of conducting the trial, on a red loamy sand, typical of the region.

Design
Treatments were replicated four times in randomised complete blocks. Plots consisted of two pair-planted rows (4 single rows in total) on a single bed 1.6 m wide (bed centre to adjacent bed centre), 2.0 metres long.

Planting, Treatment & Establishment
Beds were unformed. All seed was hand sown 23 Jan 2010, to a depth of about 5-10 mm by marking lines for rows, creating a shallow furrow with a vee-shaped aluminium tine. Plots were then seeded by hand, by pouring seed into furrows at approximately 4 times the standard seeding rate for later hand thinning. Furrows were then lightly covered by hand.

Table 9.1.27 *BC0903: Treatment Details (seed, seed treatment and soil fungicide treatments applied)*

No.	Seed	23 Jan 2010 (Same day as Planting)	19 Mar 2010 (55 Days After Planting)
1	LX3632		
2	LX3632	Ridomil Gold 480 EC + Amistar 250 SC	Ridomil Gold 480 EC + Amistar 250 SC

Table 9.1.28 *BC0903: Product Application Rates/Application*

Product	Formulation Active Ingredient Concentration	Product Rate/ha (field)	Active Ingredient Rate/ha (field)	Effective Product Rate/ha	Effective Active Ingredient Rate/ha
Ridomil Gold 480 EC	metalaxyl-m 480g/L	781mL (0.25mL/ 0.5L/Plot)	375g	3124mL	1500g
Amistar 250 SC	azoxystrobin 250g/L	1563mL (0.50mL/ 0.5L/Plot)	391g	6252mL	1563g

Note: Treatment 5 had both fungicides combined and applied in the same water volume as treatments 3 & 4 (500mL water/plot).

Additional Data

Sclerotinia *Sclerotinia sclerotiorum* (BC0700 – Mersey Lee, Tas, 2007)
A commercial crop of black carrots harvested just before the project commenced was visited and observations recorded (See Appendix 1). With the benefit of the knowledge gained during the project, this crop was sown far too early in the spring (14 Nov 2006) to avoid severe bolting. This was the only crop encountered over the life of the project that showed serious *Sclerotinia* infection. It is very likely that the extreme vigour of the crop canopy coupled with the cool and wet conditions that favoured the disease in this instance did not occur at the other sites, resulting in much less disease pressure.

It seems then *Sclerotinia* can severely infect black carrots. The larger and more vigorous canopies of black carrots may make them more susceptible under favourable conditions but the disease appears to be well managed under more typical summer plantings on the mainland.

Leaf Blight (*Alternaria dauci*)
Black carrots developed this disease only very late in the cropping cycle towards harvest. The disease was however seen in nearly all crops as they approached full maturity. In fact it became a reasonable indicator of crop maturity and readiness for harvest. There was no indication that black carrots were more susceptible than standard orange carrots in a wide range of project plantings. Alternaria blight is typically a disease of senescence in carrots as well as other crops such as potatoes.

Nematodes
Soil samples were taken at several sites and passed to DPI, Victoria Crop Health Services to test for the presence and levels of pathogenic nematode species. Two where severe forking occurred, and one immediately next to a severely forked site where very little forking occurred. There was no good correlation between the extent of forking and the species or levels of nematodes found as the table below shows.

Table 9.1.29 *BC0805, BC0901, BC0902 & BC0905: Nematodes extracted from soil and carrot samples at harvest*

	BC0805 Parilla, SA 2009	**BC0901 Clyde, Vic 2009**	**BC0905 Clyde, Vic 2009**	**BC0902 Dareton, NSW 2009**
% Forking	57%	50-70%	8%	39%
Root-knot nematode *Meloidogyne* spp.	-	-	-	-
Root-lesion nematode *Pratylenchus* spp.	355 per 200mL soil (moderate)	-	-	-
Pin nematode *Paratylenchus* spp.	23 per 200mL soil (low)	-	-	-
Cyst nematode Heterodera schachtii	-	13 per 200mL soil (low) 13 per 10g root (low)	8 per 200mL soil (low) Nil per 10g root (low)	-

The species considered most damaging in carrots, root-knot nematode (*Meloidogyne* spp.) was not isolated in any of the soil samples taken. Other than forking, the characteristic galling associated with this species was not seen in these samples.

Root lesion nematode is associated with reddish and brown patches on tap and lateral roots (Davison & McKay 2004) rather than forking.

Pin & Cyst nematodes were only present at extremely low levels and are considered very weakly pathogenic and not related to carrot forking (Lila Nambiar, pers. comm. 2010)

Fungi isolated in "pinched" and stressed seedlings (BC0701 & BC0904)
A condition appeared in several trials, two where it was particularly severe. This condition is more fully described and discussed in Section 9.2. Plants affected were typically small, were stressed (high anthocyanin content) and very weak at the base, rather like they had been girdled. Seedling & soil samples from a commercial crop in Robinvale 2007 (BC0701) & a summer planting at Clyde, Victoria (BC0901) were sent to Crop Health Services, Vic DPI & Dr Trevor Wicks at SARDI, SA respectively.

BC0701 showed *Fusarium* was consistently present, *Sclerotium rolsii* was frequently present and *Rhizoctonia* was occasionally present.

Sclerotium rolfsi is the cause Southern blight in other countries, but is not known to be a significant problem locally. In addition, the symptoms of this are quite different to those already described. *Fusarium* and *Rhizoctonia* were not thought likely to be the primary cause of the problem and were more likely secondary infections.

On discussion with Dr Trevor Wicks and review of his paper (Coles & Wicks 2003) it was thought that perhaps *Alternaria radicina* may be the cause.

BC0904 saw the symptoms reappear in a planting made mid-summer at Clyde in Southern Victoria. A plant and soil sample was sent to SA but no *Alternaria* was isolated.

It was concluded that this condition was perhaps bacterial but more likely a physiological condition induced by heat.

References

Coles RB, Wicks TJ (2003). The incidence of *Alternaria radicina* on carrot seeds, seedlings and roots in South Australia. *Australian Plant Pathology* **32**, 99-104.

Davison EM, McKay AG (1998). *Pythium* spp. associated with cavity spot of carrots in Western Australia. *Australian Plant Pathology* **27**, 163-168.

Davison EM, McKay AG (1999). Reduced persistence of metalaxyl in soil associated with its failure to control cavity spot of carrots. *Plant Pathology* **48**, 830-835.

Davison EM, McKay AG (2003). Host range of Pythium sulcatum and the effects of rotation on Pythium diseases of carrots. *Australian Plant Pathology* **32**, 339-346.

Davison EM, McKay AG (2004). Carrot Diseases VEGEnotes – Spring 2004, HAL ISSN: 1449-1397

9.2 Heat Effects on the Germination, Establishment & Yield of Black Carrots

Introduction

Poor germination is a frequent problem in all carrots, not just LX3632. From the outset though, this was a particularly severe problem with LX3632 and a variety of causes were suspected of potentially contributing to poor germination and stand establishment. These causes included soil or seed borne diseases associated with damping off, seed viability, unusual sensitivity to herbicides and temperature at planting. Within the broad scope of these project studies there were limits to the work that could be undertaken. However, considerable progress in finding or eliminating these factors was made. Seedling disease and herbicide sensitivity are examined in sections 9.1 & 9.3. This section looks at the likely role heat plays directly and indirectly in reducing emergence and reducing yield and quality in crops of black carrots.

References

Mason B (1958) Soil Temperatures – Giles, Western Australia. *Australian Meteorological Magazine 1959 Papers*, Australian Bureau of Meteorology.

Weather Data – Australian Bureau of Meteorology & on site records – NSW, DPI, Dareton.

Key Outcomes

- High temperature is likely to be the key cause of poor black carrot germination and establishment in summer plantings.

- Seed should never be planted into a hot, dry seed bed (soil temp exceeds 30°C). This may entail planting at night and/or pre-watering.

- Better management of carrot seed to avoid high losses in viability from being subjected to heat is an enormous industry problem and requires future work.

- The limited window for planting LX3632 to avoid early bolting in southern Australia, places it in a potentially very hostile temperature range for germination and establishment.

- After planting, seed must always be hydrated and the top 5mm never allowed to dry out until plants are established and roots are seen to extend down to moisture. This may involve watering every 1-2 hours during the hottest period of the day when extreme heat or soil temperatures in the top 5mm exceed 30°C, although very little moisture (eg. 2mm) need be applied if moisture below 5mm of soil depth is good.

- All care needs to be taken to ensure black carrot seed is kept in appropriate cool & dry storage and never allowed to reach temperatures above 30°C before use.

- Carrot seed loses viability very seriously and very quickly on seed tape. The exact mechanism for this is unclear. Seed towards the centre of the spool is more affected than seed towards the outside. This suggests either pressure or lack of oxygen may play a key role.

- Distinctive neck pinching symptoms appear to be heat related. Neck pinching in seedlings is associated with a weakness at this point, limp plants, high petiole anthocyanin expression and seedlings often die shortly after symptoms appear. The rapid rate of early growth in black carrots seems to make them more prone to vascular tissue being injured by extreme heat as the seedling emerges.

- Climates which are capable of balancing the heat requirements to avoid early bolting but simultaneously avoid the extreme heat of southern summers during establishment are the most suitable for black carrot production. This may well mean the best production should be shifted to more coastal regions during the summer and northern regions during the cooler months.

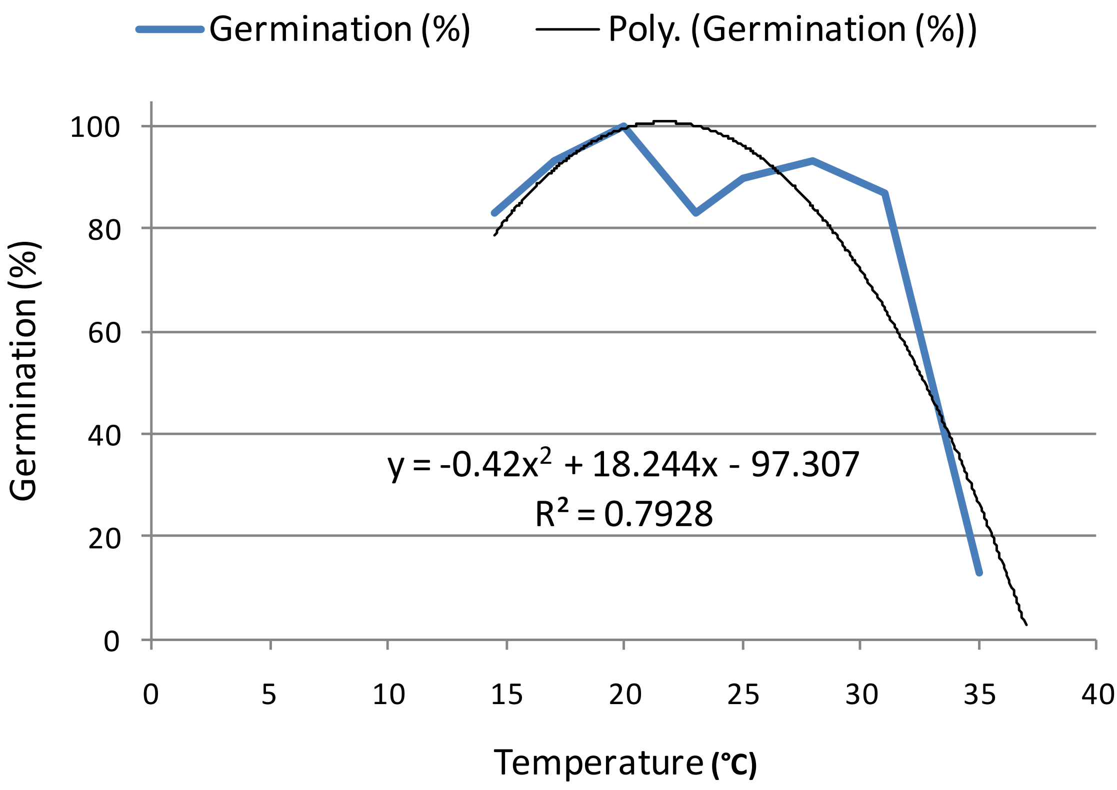
- Forking occurred at a much higher incidence in trials established during very hot weather. Plantings delayed by only a week or two, placing them into a slightly cooler window for example, showed dramatically lower levels of forking.

BC0809 - Thermogradient Table Study

This was a trial conducted by South Pacific Seeds (SPS) at their seed laboratory in Griffith. It is a way of determining the temperature sensitivity of seed without being deprived of water. In field situations, warmer ground means higher evapotranspiration, so high surface soil temperatures are associated with higher average levels of soil dryness in the absence of extra irrigation. The “Final Shoot Count %” has been simply referred to as “Germination %”. Strictly though the thermogradient results are based on a shoot count. The seedlings are not left to develop to the full length as in the case of a normal germination test. The results are intended to provide a guide to the performance of a seed lot over a range of temperatures.

***Figure 9.2.1** – BC0809: Thermogradient Table Study – Final Shoot Count % of LX3632 following Exposure to a Range of Temperatures (Reproduced & modified by AHR, courtesy of SPS)*

Product: 4001806 Carrot LX3632
Batch: 4007444 Lot: 4001806-AA
TEST DATE: 10 October 2008



The results show very clearly the extreme sensitivity of LX3632 to germination temperatures in excess of 31°C. This immediately points to problems in crops being planted in the summer in southern Australia. AVERAGE daily maximum temperatures for Mildura are 32.2°C in January and 31.6°C in February (Section 8).

The Bureau of Meteorology publish soil temperatures on their website but the shallowest references are 5-10 cm. However, studies such as one conducted at Giles in WA in 1957, showed temperatures at 2.5cm depth reaching an average maximum of 56.9°C at 2:30pm for January. Furthermore the soil temperature was above 30°C from 08:30am until after 10:30pm during Jan with the peak at 2.30pm (Mason, 1958). While this may be an extreme example from the WA desert, ambient temperatures in the Mildura region are frequently among the highest in the country in the Jan-Feb period. Carrot seed is usually planted about 5-10mm deep, typically at the shallower end of that range. It is reasonable then to expect similar temperatures can occur in this environment in the absence of adequate irrigation.

Project Case Studies where Heat was implicated in Poor or Failed Emergence

Case Study 1 - BC0901 (Clyde, Victoria, 2009)

Materials and methods for this trial can be found in Section 9.1.

Table 9.2.1 *– BC0901 – Planting **1***
Sown 15 Jan 2009

Date	Max Temp (°C)	Min Temp (°C)	Av. Temp (°C)
15/01/2009	22.8	13.5	18.1
16/01/2009	19.1	12.5	15.8
17/01/2009	18.5	11.1	14.8
18/01/2009	23.0	7.2	15.1
19/01/2009	35.0	9.5	22.3
20/01/2009	38.0	15.0	26.5
21/01/2009	27.0	12.0	19.5
22/01/2009	33.0	14.0	23.5
23/01/2009	29.4	11.0	20.2
24/01/2009	22.0	15.0	18.5
25/01/2009	25.5	8.0	16.8
26/01/2009	23.0	11.0	17.0
27/01/2009	35.5	12.0	23.8
28/01/2009	42.1	14.5	28.3
29/01/2009	44.0	20.8	32.4
30/01/2009	43.5	23.0	33.3
31/01/2009	30.1	19.1	24.6
1/02/2009	26.5	17.5	22.0
2/02/2009	27.6	17.0	22.3

Temp>31.0
Temp>35.0

Frequent small irrigation events applied to keep top few mm moist →

Table 9.2.2 *– BC0901 – Planting **2***
Sown 15 Jan 2009

Date	Max Temp (°C)	Min Temp (°C)	Av. Temp (°C)
3/02/2009	28.0	18.8	23.4
4/02/2009	32.5	18.0	25.3
5/02/2009	29.5	17.0	23.3
6/02/2009	39.5	15.5	27.5
7/02/2009	46.0	16.0	31.0
8/02/2009	20.5	15.5	18.0
9/02/2009	20.0	12.5	16.3
10/02/2009	19.0	10.0	14.5
11/02/2009	18.8	12.0	15.4
12/02/2009	20.4	10.6	15.5
13/02/2009	24.5	10.2	17.3
14/02/2009	27.4	8.0	17.7
15/02/2009	28.0	15.6	21.8
16/02/2009	27.7	15.5	21.6
17/02/2009	28.9	13.8	21.3
18/02/2009	29.3	12.1	20.7
19/02/2009	29.0	12.5	20.8
20/02/2009	23.0	15.0	19.0
21/02/2009	21.0	15.3	18.2
22/02/2009	24.5	15.0	19.8
23/02/2009	33.5	13.5	23.5
24/02/2009	20.3	10.5	15.4

Photograph 9.2.1*: BC0901 – First sowing attempt. Seedling emergence on 2 Feb 2009, 18 days after planting at 4x standard rate (sown 15 Jan 2009)*

Photograph 9.2.2*: BC0901 – Second (successful) sowing attempt. Seedling emergence on 24 Feb 2009, 21 days after planting at 4x standard rate (sown 3 Feb 2009)*

Photograph 9.2.3*: BC0901 – Some losses in second (successful) sowing attempt. Seedling emergence on 24 Feb 2009, 21 days after planting at 4x standard rate (sown 3 Feb 2009)*

Photograph 9.2.4*: BC0901 – Stressed but surviving seedlings in second (successful) sowing attempt. Seedling emergence on 24 Feb 2009, 21 days after planting at 4x standard rate (sown 03 Feb 2009)*

Watering (8mm) was carried out daily, usually before dawn but not again for 24 hours. When the first planting failed there was concern it may be herbicide damage. However the grower had lost all his own plantings made around the same time. After the second planting was made, temperatures were monitored. On 6 Feb, the area was irrigated more than once. On 7 Feb 2009 (Black Saturday), the crop was watered every 2 hours with 1-2mm irrigation four times during the hottest part of the day, keeping the top few mm of soil moist, until a cool change came through. The wetting and cooling effect gave adequate protection.

Case Study 2 - BC0805 (Parilla, SA, 2009)
The fourth planting in a sequence of 5 designed to cover the growing season, was planted 27 Jan 2009. This crop received 2 daily applications (sometimes 3) of 4mm/irrigation through a centre-pivot system. There are no photographs but by way of contrast with BC0901 (Case Study 1) and BC0902 (Case Study 3) which survived, BC0805 was destroyed on Black Saturday (7 Feb 2009).

Case Study 3 – BC0902 (Dareton, NSW, 2009)
After very uneven germination was experienced through use of trickle irrigation during germination, the first planting had to be sprayed out and replanted. At the time however, there was some concern as with BC0901 that pre-emergent herbicides may have contributed to the damage. The second planting was made the day before BC0805 at Parilla (above). This second planting survived as it was receiving three overhead watering events daily, covering the hottest part of the day.

Table 9.2.3** – BC0805 – Planting **4
Sown 27 Jan 2009

Date	Max Temp (°C)	Min Temp (°C)	Av. Temp (°C)
27/01/2009	42.6	18.5	30.5
28/01/2009	45.5	20.4	32.9
29/01/2009	44.8	26.1	35.4
30/01/2009	44.9	24.5	34.7
31/01/2009	44.2	22.7	33.5
1/02/2009	40.2	24.2	32.2
2/02/2009	40.6	24.2	32.4
3/02/2009	37.6	18.2	27.9
4/02/2009	38.4	17.2	27.8
5/02/2009	36.1	16.0	26.0
6/02/2009	42.9	15.3	29.1
7/02/2009	47.6	22.3	34.9

Table 9.2.4** – BC0902 – Planting **1
Sown 08 Jan 2009

Date	Max Temp (°C)	Min Temp (°C)	Av. Temp (°C)
8/01/2009	29.5	13.0	21.3
9/01/2009	30.5	13.0	21.8
10/01/2009	33.0	13.0	23.0
11/01/2009	35.0	15.0	25.0
12/01/2009	37.0	17.0	27.0
13/01/2009	39.0	20.0	29.5
14/01/2009	43.0	21.0	32.0
15/01/2009	31.0	16.0	23.5
16/01/2009	31.0	13.0	22.0
17/01/2009	32.0	12.0	22.0
18/01/2009	36.0	16.0	26.0
19/01/2009	40.5	20.0	30.3
20/01/2009	43.0	22.0	32.5
21/01/2009	39.0	20.0	29.5
22/01/2009	38.0	23.0	30.5
23/01/2009	34.0	20.0	27.0

Table 9.2.5** – BC0902 – Planting **2
Sown 26 Jan 2009

Date	Max Temp (°C)	Min Temp (°C)	Av. Temp (°C)
26/01/2009	41.0	19.0	30.0
27/01/2009	44.4	21.0	32.7
28/01/2009	45.0	29.0	37.0
29/01/2009	44.0	29.0	36.5
30/01/2009	45.0	28.0	36.5
31/01/2009	45.5	29.0	37.3
1/02/2009	45.0	27.0	36.0
2/02/2009	45.5	27.0	36.3
3/02/2009	42.5	26.0	34.3
4/02/2009	42.0	23.0	32.5
5/02/2009	43.0	22.0	32.5
6/02/2009	45.0	23.0	34.0
7/02/2009	48.0	29.0	38.5
8/02/2009	35.0	22.0	28.5
9/02/2009	28.5	15.0	21.8
10/02/2009	26.0	12.0	19.0

The extreme heat in both Parilla and Dareton is evident not just through the string of extremely hot days but in some cases extremely hot nights as well. Given seed viability drops to 13% at 35°C the extreme danger this environment presents to seed is obvious.

Importantly, the results from the trials show that even under these extreme conditions, watering much more frequently and evenly can make germination successful. This is shown by the contrasting results in BC09002 Planting 2 which still managed to germinate moderately well even under worse conditions than experienced in the earlier planting that failed to germinate with trickle only irrigation. Comparing BC0805 planting 4 with BC0902 planting 2 which were both made at almost the same time with a centre-pivot system (BC0805) and solid-set sprinklers watering three times daily covering the hottest period.

Case Study 4 – BC0701 – Early project commercial LX3632 Crop, Robinvale, Victoria

For full details, please refer to Appendix 1.

Below are some photographs taken of plants with distinctive pinching at the base of the plant causing extreme plant weakness and very often plant death. The cause was originally thought to be possibly herbicidal or disease related but subsequent testing and the occurrence of these symptoms in other studies planted in periods of great heat (eg. Case study 1 – BC0901) with insufficient watering frequency makes extreme heat the likely cause. It appears that the rapid rate of growth with LX3632 makes the soft cellular material near the base unusually sensitive to heat damage. This has the effect of damaging the phloem, often to the point the plant fails to grow beyond a seedling before either breaking or simply being unable to grow any larger and dying. It is possibly related to the symptoms seen in seedlings in photos 9.2.3 & 9.2.4.

Photo 9.2.5 *BC0701 – Severely "pinched" and weakened seedling where the stem connects to the carrot at the crown showing how little healthy vascular tissue remains intact*

Photo 9.2.6. *BC0701 – Extreme examples of seedlings “pinched” and weakened where the stem connects to the carrot at the crown*

Forking and Heat During Establishment

All of the trials with very high levels of forking were sown under very hot conditions. Two plantings made only 9 days apart (photos 9.2.7 & 9.2.8) in adjacent beds showed dramatically different levels of forking and this could not reasonably be put down to disease or nematodes (See section 9.1).

Photograph 9.2.7*:– BC0901 Carrots highly forked (70%) & planted 03 Feb 2009*

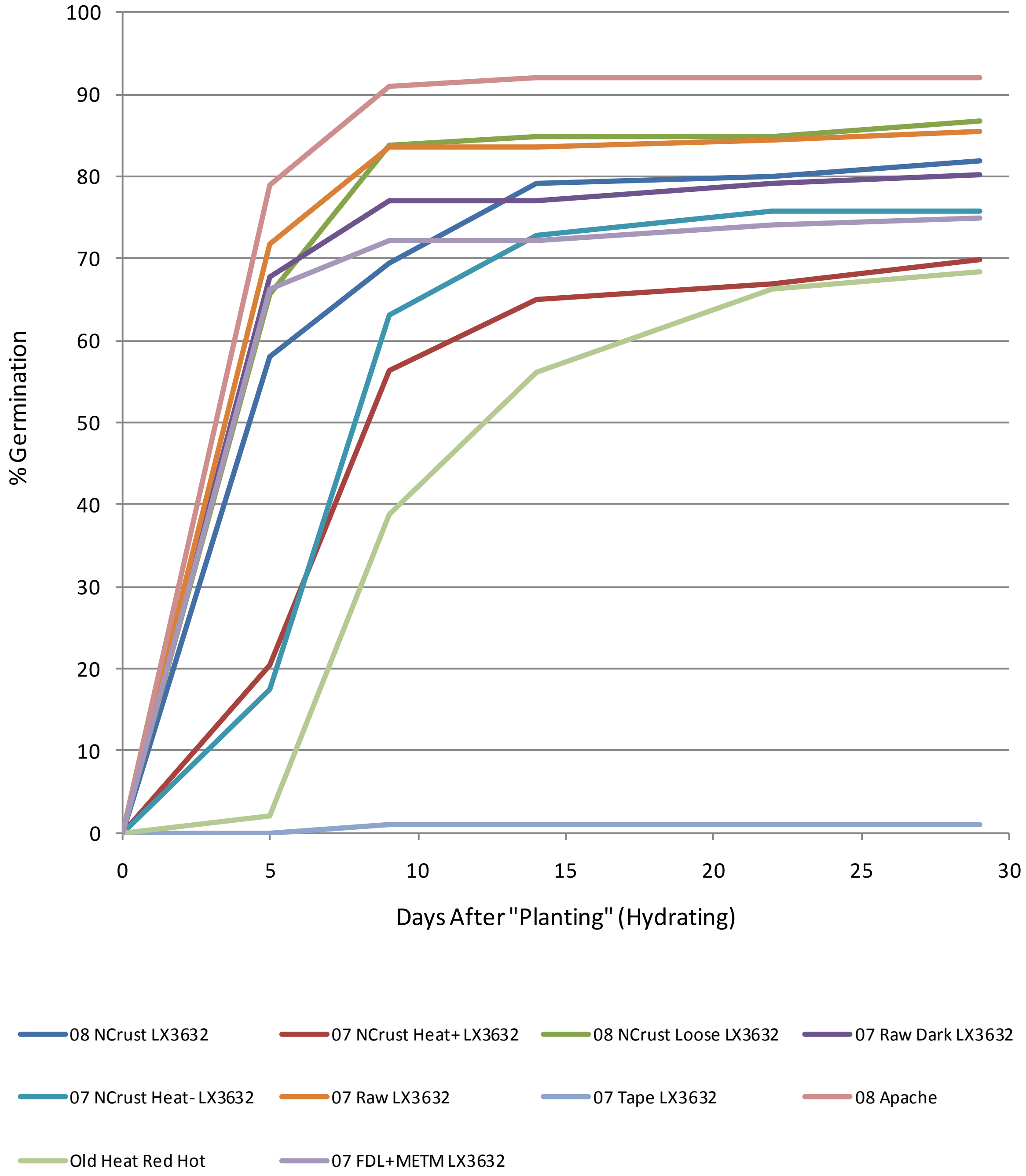
Photograph 9.2.8*:– BC0905 Carrots showing only 8% forking planted in a bed immediately adjacent to BC0901 (above) on 12 Feb 2009, just 9 days later.*

Germination test on seed subjected to different heat storage treatments

In 2008, a seed viability test was done on a range of different LX3632, Apache & Red Hot seed batches, with and without various seed dressings or seed coatings to assist vaccuum planters pick up seed. Most seed showed germination levels between 77% & 92% but the details were lost in circumstances beyond the control of AHR.

A follow up test of seed viability was done after the last field trial had been initiated and the results are shown below:

Figure 9.2.2 *– BC1001: Seed Germination Study on various batches of older seed subjected to differing storage conditions*



Design
All seed was counted (100 seeds/sample) and placed on very damp cotton wool in a container with separated plastic cells 13/01/2010. Ambient temperatures were 24-27°C throughout the 29 day period. Melbourne domestic supply water was used to top up cells daily as required, avoiding overwatering but ensuring ideal moisture at all times. Every few days (as per details) clearly germinating seeds with a shoot at least 5mm long were removed and counted. The process continued until no more seeds were found germinating. Treatments (seed lots) were not replicated.

Treatment List:

Table 9.2.6: *BC1001 – Treatment list: Seed Description for lots tested*

Seed Description	Days After "Planting" (Hydrating)					
	0	5	9	14	22	29
08 NCrust LX3632	0.0	58.1	69.5	79.0	80.0	81.9
07 NCrust Heat+ LX3632	0.0	20.4	56.3	65.0	67.0	69.9
08 NCrust Loose LX3632	0.0	65.7	83.8	84.8	84.8	86.7
07 Raw Dark LX3632	0.0	67.7	77.1	77.1	79.2	80.2
07 NCrust Heat- LX3632	0.0	17.5	63.1	72.8	75.7	75.7
07 Raw LX3632	0.0	71.8	83.5	83.5	84.5	85.4
07 Tape LX3632	0.0	0.0	1.0	1.0	1.0	1.0
08 Apache	0.0	79.0	91.0	92.0	92.0	92.0
Old Heat Red Hot	0.0	2.0	38.8	56.1	66.3	68.4
07 FDL+METM LX3632	0.0	66.3	72.1	72.1	74.0	75.0

Seed Details:

08 NCrust LX3632: 2008 NCrust seed coating (clay coat to assist seed pick up). Seed was contained in a 1.0L sealed steel tin with a pry open lid. It was taken to the field on several occasions but not subjected to direct sun with the lid on. It was transported in an air conditioned car and covered with insulating blanket if left in a vehicle, out of direct sun, windows down.

07 NCrust Heat+ LX3632: 2007 NCrust seed coating (clay coat to assist seed pick up). Seed was contained in a 1.0L transparent plastic sealed container. It was taken to the field on several occasions and sometimes subjected to direct sun with the lid on. It was transported in an air conditioned car and covered with insulating blanket if left in a vehicle, out of direct sun, windows down.

08 NCrust Loose LX3632: 2008 NCrust seed coating (clay coat to assist seed pick up). Seed was originally contained in a 1.0L sealed steel tin with a pry open lid but removed and kept in a brick room, typically no warmer than 25-27°C in the summer, always out of direct sun in a 7x10cm resealable plastic bag. It was taken to the field only once. It was transported in an air conditioned car and covered with insulating blanket if left in a vehicle, out of direct sun, windows down.

07 Raw Dark LX3632: 2007 raw seed with NO seed dressing. 100g received in a foil/plastic, resealable 7x12cm seed bag during spring. Seed was occasionally opened for samples to be removed then resealed. The bag remained in a brick room, typically no warmer than 25-27°C in the summer. The package was never taken outside of the room.

07 NCrust Heat- LX3632: Identical to 07NCrust Heat+ LX3632 except it was separated from the 07NCrust Heat+ LX3632 and subjected to one less field trip undertaken during a heat period, and stored in a separate 1.0L plastic container less well sealed.

07 Raw LX3632: Identical to 07 Raw Dark LX3632 but separated and kept in a small 4x6cm, clear, resealable plastic bag, occasionally opened, but never taken to the field.

07 Tape LX3632: This was a remaining portion of the seed tape originally used to plant BC0801 from about the last quarter of a spool (closest to the centre). It was on the outside of the spool when taken. After initial use for BC0801, the spool was stored in a brick room, typically no warmer than 25-27°C in the summer, always out of direct sun in a card box.

08 Apache: 2008 seed supplied by cooperating grower who kept the seed cool stored. It was kept from Jan 2009 in a large 25x40cm resealable plastic bag in a brick room, typically no warmer than 25-27°C in the summer, always out of direct sun and never taken to the field.

Old Heat Red Hot: Exact age unknown but at least 5 years. Seed had been stored in a white sealed 15.0L plastic bucket with a pry open lid. It had spent most of this time in a north facing office, not subjected to direct sun but with variable ambient temperatures reaching more than 30°C on occasions. From Jan 2009 it was transferred to a clear 1.0L plastic container with a screw on lid and stored in a brick room, typically no warmer than 25-27°C in the summer, always out of direct sun. It was taken to the field on several occasions but not subjected to direct sun with the lid on. It was transported in an air conditioned car and covered with insulating blanket if left in a vehicle, out of direct sun, windows down.

07 FDL+METM LX3632: 2007 seed treated with fludioxonil (not currently registered for use in carrots) and metalaxyl-m as per trial BC0705. It was taken to the field on several occasions but not subjected to direct sun with the lid on. It was transported in an air conditioned car and covered with insulating blanket if left in a vehicle, out of direct sun, windows down.

Key findings:

- Any exposure to heat, even during normal handling is potentially more detrimental to seed viability than seed age (up to several years old). 2-3 year old seed is more viable when well stored than younger seed experiencing common handling procedures that subject seed lots to short periods of exposure to temperatures above 30°C.
- Standard orange processing carrot seed loses vigour (speed of emergence) when it is old as well as viability. Young seed, well stored and kept in good condition, even if not specifically cool stored showed 92% viability and had mostly emerged (high vigour) within 9 days (08 Apache).
- LX3632 stored under good conditions though not actually cool stored showed good viability (86-87%) even after 2 years particularly when no seed treatment or only NCrust was applied. The rate of germination (vigour) was comparable to Apache in good condition.
- There is no reason to believe LX3632 seed is any more susceptible to heat or age related loss of viability than standard orange processing types like Apache or Red Hot.
- Seed Tape can be extremely detrimental to carrot seed viability and should not be used until the causes are better understood.
- Fludioxonil and metalaxyl-m showed no obvious signs of reducing seed viability although some damage from exposure to heat complicated this.
- ALL RESULTS ARE BASED ON SINGLE SAMPLES and should be used as relative indicators in the context of this trial and not absolute indicators of likely germination rates in the field.

9.3 Black Carrot Tolerance to the Herbicides Linuron & Prometryn

Introduction

At the beginning of the project there was concern that black carrots may be much less tolerant to commonly used carrot herbicides than conventional orange carrots. Early stem “pinching” symptoms, very poor and patchy emergence or stunted and purple plants emerging were all suspected of being related to a number of causes including herbicides.

A variety of herbicides registered for uses in other crops but not carrots in Australia, but used in carrots overseas may also be suitable. However, these were not looked at and considered outside the line of enquiry being pursued in this project. Two selective herbicides currently registered for use in carrots in Australia are linuron (eg. Linuron®) and prometryn (eg. Gesagard®). Both are highly effective against a wide range of mainly broadleaf weeds and have been shown to have good selectivity in carrots when used both pre and post emergence of both the crop and the weeds. With the ability to take most grass weed problems out with the selective post-emergent herbicide (Fusilade® Forte), this in fact makes carrots among the better catered for crops in terms of selective herbicide options.

Both of these herbicides have a similar mode of action, belonging to resistance group C (inhibitors of photosynthesis at photosystem II). However, prometryn belongs to the triazine chemical family and linuron the ureas (CropLife Australia, 2009). Carrot growers appear to very often use much lower rates than labels recommend for reasons of both adequate efficacy at lower rates and alleged improved crop safety. Further, these products are often used in combination with each other and there are no recommendations on either herbicide label for mixing these products.

Both of these herbicides were used in several of the project studies for weed control at label rates but usually in combination with each other, both pre and post crop emergence. After some problems with poor emergence in several trials where pre-emergent applications of these herbicides had been made, a single dedicated study examining pre-emergence tolerance to both prometryn and linuron was also undertaken to try to resolve any specific selectivity issues related to black carrots.

References

CropLife Australia (2009). Herbicide Mode of Action Groups (Sep 2009) http://www.croplifeaustralia.org.au/files/resistancemanagemen/herbicides/2009%20Herbicide%20MOA%20Table.pdf

Key Outcomes

- LX3632 tolerated pre-emergent applications of linuron and prometryn similarly to conventional orange carrots. Growers should apply these herbicides in the same way to LX3632 as to ordinary carrots.

- When applied pre-emergence of the crop and outside of periods of extreme heat, the effects of high use rates of either of these herbicides were seen as a reduced canopy volume rather than in seedling losses leading to poor plant establishment.

- Losses incurred when plantings are made in extreme heat may be compounded by high rates of linuron and prometryn.

- Post-emergent tolerance of LX3632 appears similar to conventional orange carrots. Care needs to be exercised with LX3632 where a staggered germination may result in a wide range of crop growth stages, as seedlings with less than 4 true leaves may be susceptible to damage.

- These herbicides provide carrot growers with more reliable and selective pre and post-emergent control of a wide range of weeds, than is typically available in many other vegetable crops.

Additional Data Collected BEFORE Conducting the Main Study

Early on after the project had commenced, anecdotal observations tended to suggest, black carrots (LX3632) did not show any particular signs of heightened sensitivity based on the low rates of herbicide used in some commercial strips. Observations showed good tolerance in LX3632 when used on sufficiently mature seedlings (4+ leaf). However some subsequent crop failures in trials following pre-emergent applications of the herbicides raised some concern that perhaps these herbicides were causing or at least exacerbating damage caused by other factors.

In particular the much lower rates growers commonly use compared with label rates suggested there are concerns with crop damage at higher rates. At the same time these crop failures had occurred after some very severe heat during the germination period when maintaining consistently high soil moisture was almost impossible to do. Following this the major study was instigated to address the basic question of crop safety when making pre-emergent applications of prometryn and linuron.

The table below shows the main uses and observations after applications of the herbicides had been made to trials prior to the main study:

Table 9.3.1 *- Rates of linuron and prometryn used in various studies for weed control in crops of LX3632, prior to the main study (BC0910) being initiated.*

Trial/site	Linuron (gai/ha)	Prometryn (gai/ha)	Crop stage	Observations
BC0801 Dareton, NSW	1100	1100	30 DAS Crop 2-3 Leaf.	Plant 3+ leaf plants virtually unaffected but some very small plants were killed. *See photo 9.3.1*
BC0901 Clyde, Vic	1100	550	1 DAS. Pre-emergence of Crop	Very poor emergence and nearly all seedlings died. Herbicide **may** have compounded physiological damage induced by heat and wind. See photos 9.2.1-9.2.4
BC0902 Dareton, NSW	1100	1100	1 DAS. Pre-emergence of Crop	Very poor emergence and many seedlings died. Herbicide **may** have compounded physiological damage induced by heat and wind.
Various	225		Pre & post emergenence applications made by growers	No symptoms any time. Safe used pre and post-emergence.

***Photo 9.3.1** – Crop damage seen on oldest leaves of the smallest plants 13 days after applying 1100gai/ha linuron + 1100gai/ha prometryn to 3+ leaf stage LX3632. Some seedling death among smallest plants. Note excellent weed control. There are no label recommendations for tank mixing these two herbicides.*

Pre-emergence Tolerance of Black Carrots (LX3632) to Prometryn and Linuron

Materials & Methods (BC0910 – Tyabb, Vic, 2010)

Location
This trial was located near Tyabb (approx: 38° 09′ 05″ S, 145° 20′ 38″ E) inside a dedicated bay separate from commercial bunching vegetable crops (Dutch Carrots, Bok-Choy, Bunching onions etc), on very light sandy black soil, typical of the region.

Design
LX3632 treatments were replicated three times in randomised complete blocks. Plots consisted of three pair-planted rows (6 single rows in total) on a single bed 1.6 m wide (bed centre to adjacent bed centre), 3.0m long. A single boom width of 1.5 m (3 jets at 50cm spacings) was more than adequate for evenly applying products to the width of the bed sprayed. Wind was variable mainly from the west at ~2-4m/s.

Planting, Treatment & Establishment
The Trial was initiated in spring to avoid any interactions from extreme heat. Beds were formed several days before planting. Seed was planted 27 Nov 2009 using a commercial vacuum type seeder. Several seed lots were used, but each lot sown in a dedicated row set among commercial rows of the Dutch carrot variety "Mokum" (Bejo).

Herbicides treatments were all applied 28 Nov 2009, apart from the grower standard treatment (Trt 12) applied the day before (immediately after sowing) to beds immediately adjacent to the dedicated LX3632 bed. All applications were made in multiples of 128L/ha (treatments 2 & 6 receiving a single pass at this volume to apply the desired rate). Application was made under steady light rain which was ideal for incorporating the herbicide. This also negated any differences in spray application volumes used. Temperature was 20°C.

Irrigation
Irrigation was provided by solid set sprinklers arranged in a square grid pattern with 10 metres between risers. Irrigation intervals were determined by the grower and scheduled as for the rest of the farm, typically one to two applications of 4-5 mm/day depending on temperatures and rainfall.

Nutrition
Grower applied based on site history and soil nutrition history.

Maintenance
Other than the trial treatments, no other crop protection chemicals were used.

Assessments
Emergence (plants/1.0m of bed/plot) was measured 11 & 41 days after planting (09 Dec 2009 & 07 Jan 2010). Any symptoms of phytotoxicity or varying relative canopy biomass were noted if they occurred. A visual canopy biomass rating was made 41 days after planting. Photos were also taken of key plots at key assessments.

Statistical Analyses:
In all tables shown, vertical bars aligned in the same column indicate means that are NOT SIGNIFICANTLY DIFFERENT (LSD, P=0.05). Means followed by "-" failed Bartlett's Chi-squared Test for Homogeneity of Variance and attempts to rectify this with transformations were NOT successful (P=0.05). NSAP indicates no statistical analysis performed. Blue vertical bars indicate LSD results based on successfully transformed data BUT the numbers they follow are original.

Table 9.3.1 *BC0910: Treatment Details (Pre-Emergence Herbicide Treatments)*

No.	Product	Formulation	Product Rate (g or mL/ha)	Rate (g a.i./ha)
1	Untreated		0	0
2	Linuron DF	500g/kg linuron	550	275
3	Linuron DF	500g/kg linuron	1100	550
4	Linuron DF	500g/kg linuron	2200	1100
5	Linuron DF	500g/kg linuron	4400	2200
6	Gesagard 500 SC	500g/L prometryn	550	275
7	Gesagard 500 SC	500g/L prometryn	1100	550
8	Gesagard 500 SC	500g/L prometryn	2200	1100
9	Gesagard 500 SC	500g/L prometryn	3300	1650
10	Linuron DF + Gesagard 500 SC	500g/kg linuron + 500g/L prometryn	2200 1100	1100 550
11	Linuron DF + Gesagard 500 SC	500g/kg linuron + 500g/L prometryn	2200 2200	1100 1100
*12	Linuron DF +	500g/kg linuron +	3000	1500

*Treatment 12 was applied 24 hours earlier using growers commercial sprayer putting out

Results & Discussion (BC0910 – Tyabb, Vic, 2009-10)

Table 9.3.4 *BC0910: **LX3632** Plant Emergence 11 & 41 days after planting & Relative Canopy Biomass 41 days after planting, classified herbicide treatments applied.*

Treatment	11 DAP Emergence (Plants/1.0m bed)		Treatment	41 DAP Emergence (Plants/1.0m bed)		Treatment	41 DAP Relative Canopy Biomass (%)	
P550	171	I	**P550**	180	I	**Untreated**	100	I
L275	169	I	**L275**	179	I	**L275**	100	I
L2200	161	I	**Untreated**	172	I	**P275**	100	I
L1100 + P1100	157	I	**L550**	167	I	**P550**	97	I I
L1100 + P550	156	I	**P1100**	163	I	**L550**	95	I I
P275	156	I	**L1100**	162	I	**L1100**	88	I I
L550	154	I	**P275**	158	I	**P1100**	88	I I
L1100	153	I	**L2200**	154	I	**L1100 + P550**	82	I I
Untreated	153	I	**L1100 + P550**	154	I	**P1650**	78	I
P1100	152	I	**P1650**	145	I	**L2200**	77	I I
P1650	147	I	**L1100 + P1100**	140	I	**L1100 + P1100**	68	I

Notes: DAP = Days After Planting; L = Linuron; P = Prometryn; number indicates rate of active ingredient (g/ha).

Figure 9.3.1 *– BC00910: **LX3632** Plant Emergence 11 & 41 days after planting, classified herbicide treatments applied.*

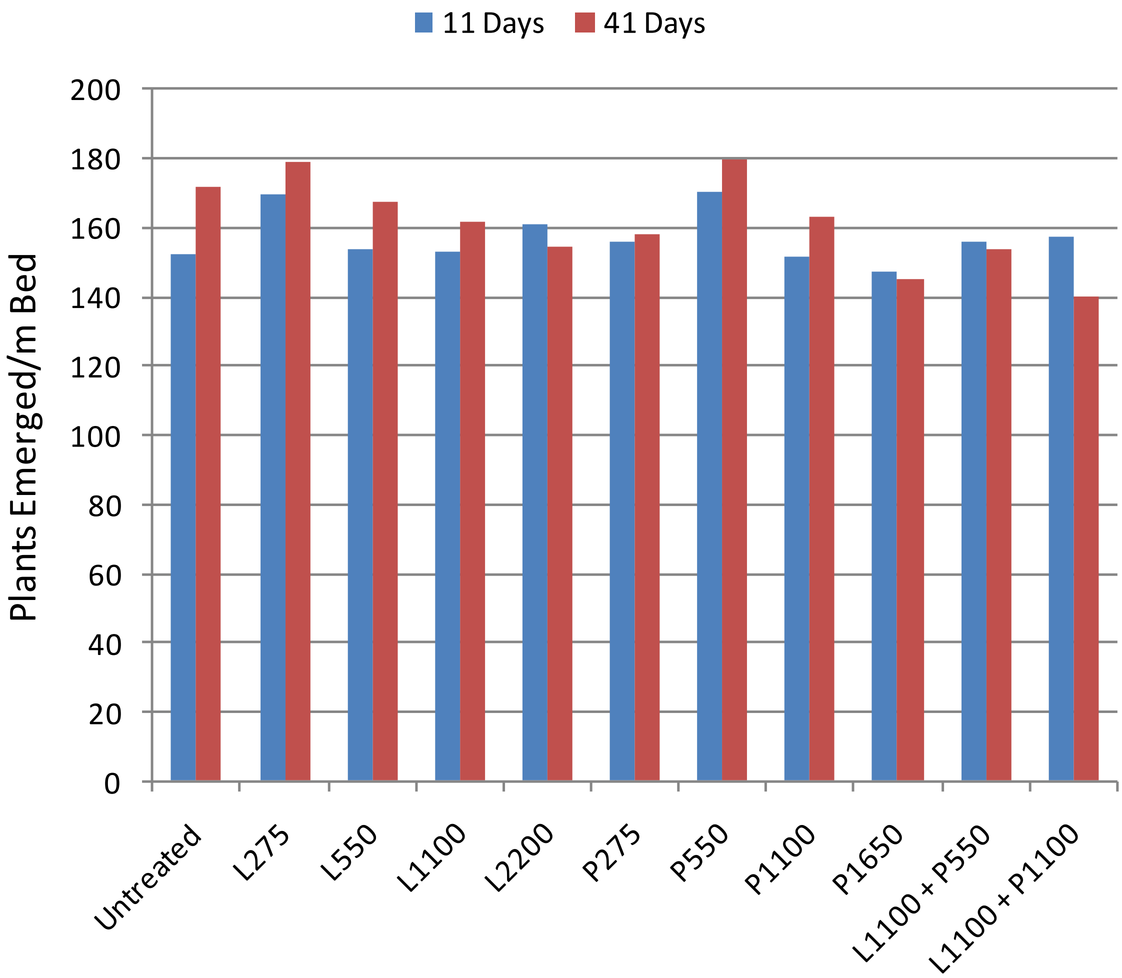


***Table 9.3.5** BC0910: **Mokum** Plant Emergence 11 & 41 days after planting & Crop Vigour 41 days after planting, classified herbicide treatments applied.*

Treatment	11 DAP Emergence (Plants/1.0m bed)	Treatment	41 DAP Emergence (Plants/1.0m bed)	Treatment	41 DAP Relative Canopy Biomass (%)
L1500 (Strong)	215 I	**L1100 + P1100**	212 I	**P550**	93 I
L1100	214 I	**L1500 (Strong)**	212 I	**L1500 (Strong)**	93 I
P1650	209 I	**P550**	208 I	**L1100**	90 I I
P550	200 I	**P1650**	204 I	**P1100**	85 I I
L1100 + P1100	200 I	**P1100**	199 I	**P1650**	78 I I
P1100	193 I	**L1100**	197 I	**L1500 (Weak)**	78 I I
		L1500 (Weak)	169 I	**L1100 + P1100**	68 I

Notes: DAP = Days After Planting; L = Linuron; P = Prometryn; number indicates rate of active ingredient (g/ha).

***Figure 9.3.2** – BC00910: **Mokum** Plant Emergence 11 & 41 days after planting, classified herbicide treatments applied.*

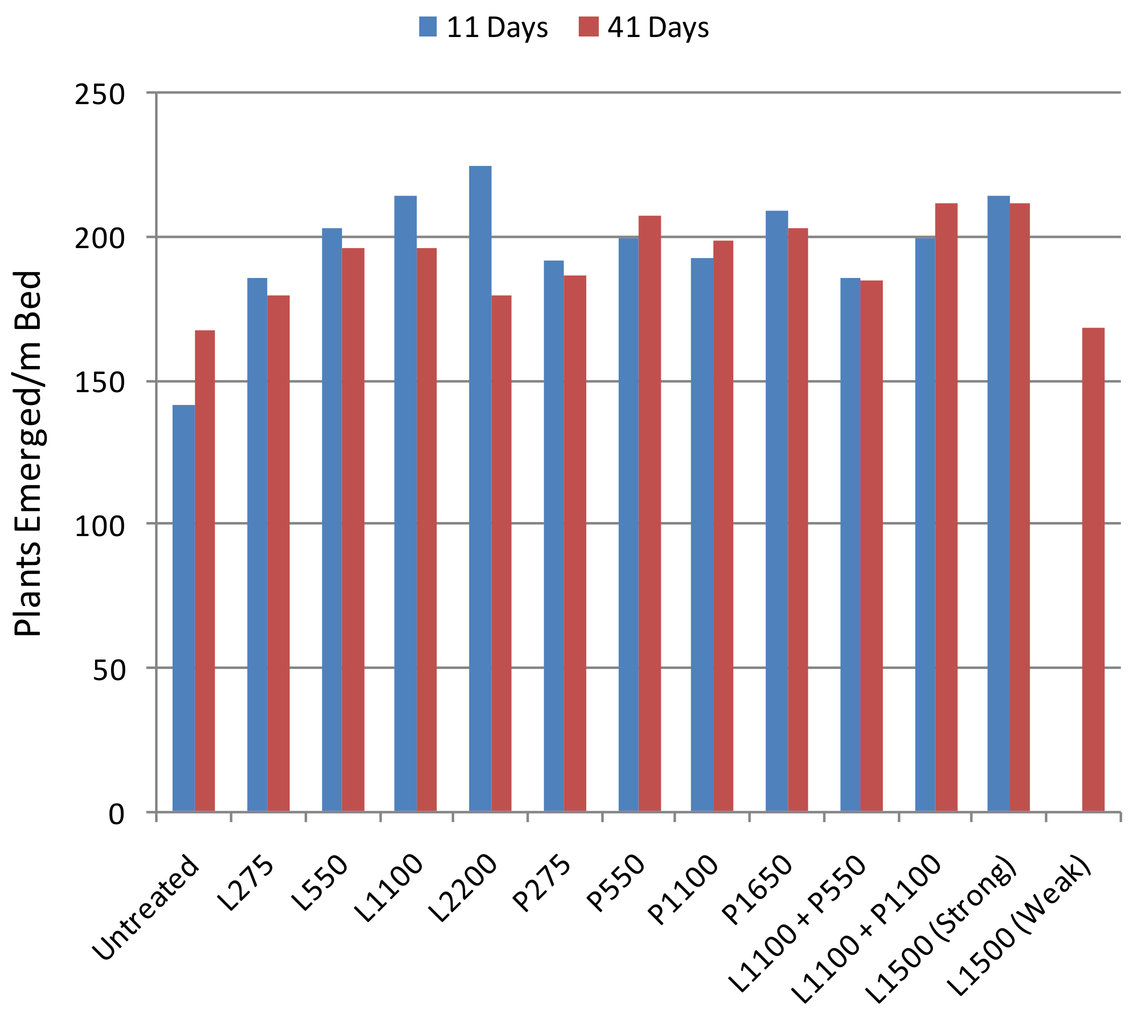


Figure 9.3.3 *– BC00910:* ***LX3632*** *Relative Canopy Biomass 41 days after planting, classified herbicide treatments applied.*

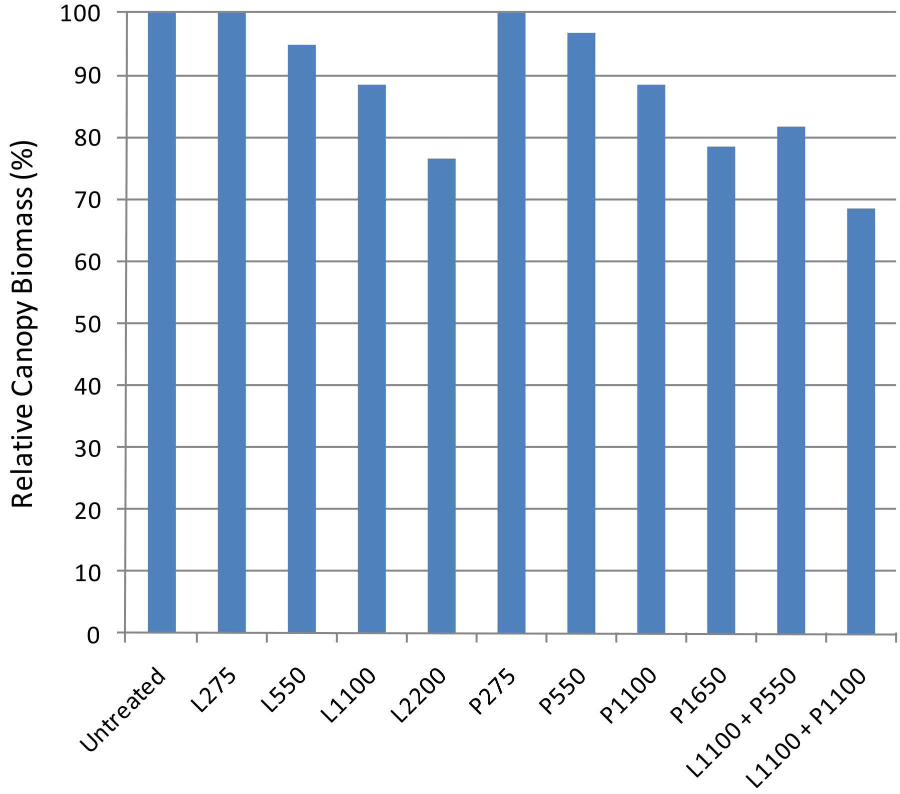
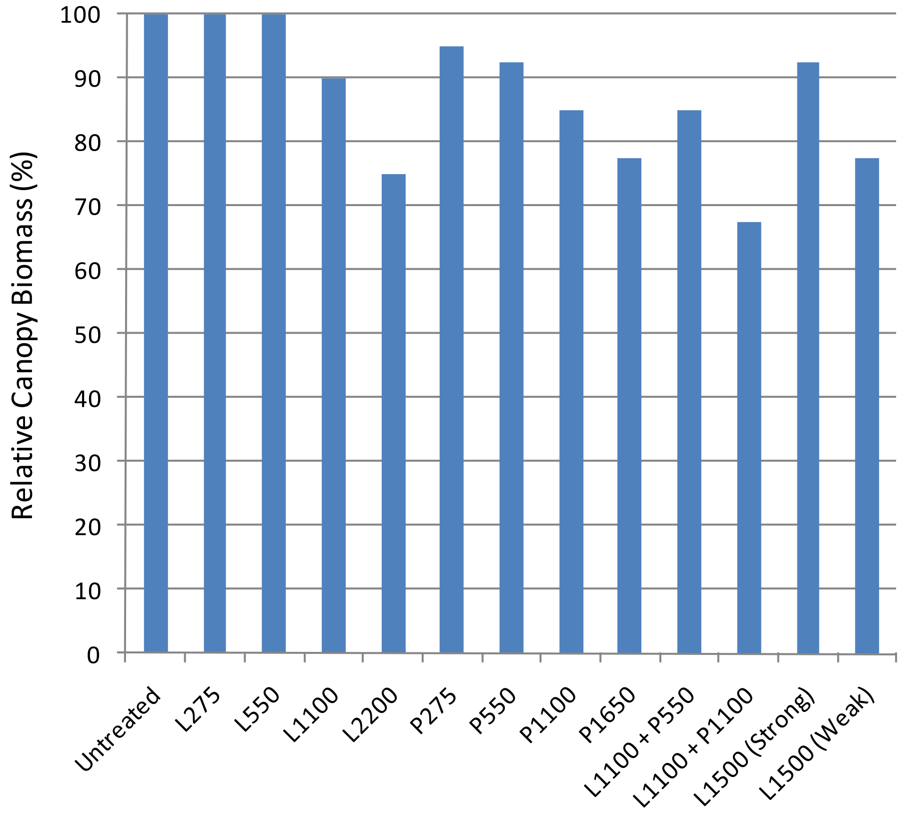


Figure 9.3.4 *– BC00910:* ***LX3632*** *Relative Canopy Biomass 41 days after planting, classified herbicide treatments applied.*



Discussion (BC0910 – Tyabb, Vic, 2009-10)

There were three replications of all LX3632 treatments but only two replications for treatments 4, 7, 8, 9, 11 & 12 in Mokum. In addition there was no treatment 12 for LX3632 as this was the grower applied (boom sprayed) standard treatment used by the grower over his entire crop. Further, the replicated section of Mokum was several beds away from the LX3632 section. There was a clear paddock effect with much weaker plants and emergence in the replicated Mokum section. This meant the grower's Mokum crop immediately surrounding LX3632 was considerably more vigorous and healthy (labeled "Strong") than the same reference in the replicated Mokum section (labeled "Weak").

From the above, the "Strong" L1500 treatment in the Mokum results can be compared directly to the results in the LX3632 tables and figures.

Emergence (Tables 9.3.4 & 9.3.5 Figures 9.3.1 &9.3.2)

There were no indications that emergence was adversely affected by any of the herbicide treatments applied or that LX3632 was any more or less sensitive than Mokum.

LX3632
Results show around 90-95% emergence had occurred in the first 11 days with little further emergence by 41 days. There was no clear indication any treatments reduced the rate of emergence.

There were no significant differences in final emergence levels between treatments. There was a weak trend towards slightly lower levels of emergence with 1650g/ha prometryn or combinations of 1100g/ha linuron + 550-1100g/ha prometryn, with slightly reduced plant numbers at 41 days compared with 11 days.

The strong Mokum reference indicates seed viability of LX3632 to be about 80% of the former.

Mokum
Results for Mokum show full emergence had occurred in the first 11 days often with slightly reduced numbers by 41 days. There was no clear indication any treatments reduced the rate of emergence.

There were no significant differences in final emergence levels between treatments. The difference between the strong & weak reference treatments show the problems described above and that variations were a function of some soil factor quite apart from the herbicide treatments applied in the trial.

There is no emergence figure for the weak Mokum reference at 11 days as the decision to make separate strong and weak reference measurements was only made once the differences in the field became evident as the crop became more established.

Relative Canopy Biomass (Tables 9.3.4 & 9.3.5 Figures 9.3.3 &9.3.4)

It is important to note these visual ratings were not assessments of crop yield and were not evaluated beyond 41 days to see whether the effect was sustained or not.

These were visual estimates, not weight based measurements. There was no indication, even at the highest rates that canopies were discoloured. The relative biomass differences would not have been clear without the immediate and adjacent comparisons that such a trial made available.

Bearing this in mind, the grower standard (strong) of 1500g/ha linuron showed around a 10-20% reduction in relative canopy biomass in Mokum.

While no treatment was found to clearly affect emergence there was a well established relationship between increasing herbicide rates and relative canopy biomass in both varieties. Allowing for subtle differences inherent in such assessments, the responses of both varieties were remarkably similar across rates and herbicides.

There was some suggestion LX3632 may be marginally more sensitive than Mokum at similar herbicide rates but this would really require further studies for confirmation given the issues described in the replicated Mokum area of the trial.

Both varieties tolerated linuron well at 275-550g/ha but showed a decline in relative canopy biomass above this rate. Prometryn was well tolerated at 275g/ha but showed a decline at higher rates. At the highest rates used, 2200g/ha linuron showed comparable relative canopy biomass to 1650g/ha prometryn.

Combinations of these group C herbicides had an additive effect with both treatments showing steadily declining relative canopy vigour at higher rates of prometryn.

10 Water Management for Black Carrot Production

Introduction

The much greater canopy vigour of black carrots, their higher canopy/carrot ratio, their delayed rate of carrot development and lower yields, all suggest the need for a better understanding of the water demands of commercial black carrot crops compared with conventional orange types. An important distinction here is between the carrot's ability to survive with little moisture and the requirements for growing a quality commercial crop. In cooler climates, carrots are tolerant of drought as they have a deep and dense root system (Suojala, 2000). However, it is clear with commercial summer production in Australia that high yields of quality carrots can only be achieved through good access to moisture at key stages of development.

The water requirements of black carrots became clear not just through dedicated irrigation trials but also through abundant observations in other key studies. The results of all relevant studies are presented here.

A first attempt to establish a watering trial was made in 2008, at Dareton NSW (BC0802), using fixed sprinklers that applied the same daily amount of water at different frequencies. However, very poor seed germination from using seed on tape resulted in the trial being abandoned.

In 2009, a trial was established at the same site, using buried trickle tape to apply differing daily amounts of water (greater and less than 100% of estimated daily requirement) and comparing responses from both LX3632 (black) and Red Hot carrots. While commercial production of carrots using trickle tape is currently fairly limited, this was the only way of establishing a truly replicated trial with sufficiently accurate control over moisture application. It was an extremely complex trial to set up, requiring 4 different watering regimes to be applied to 4 replications in a Latin Square design (16 plots with two varieties/plot).

References

Suojala T (2000). Pre- and postharvest development of carrot yield and quality University of Helsinki, Dep't of Plant Production, Horticulture Section. Publication No. 37.

Key Outcomes

- Black carrots require ready access to moisture throughout the cropping cycle, particularly during establishment and early development.

- Black carrots require more moisture than standard orange types to maximise yield. Black carrots show reduced **relative** yields and average carrot weights compared with Red Hot as readily available soil moisture in the critical first 4-6 weeks after planting declines.

- Under hot establishment conditions, increased watering frequency will greatly improve establishment, yield and quality for the same daily quantity of water applied (eg. 3 applications of 3 mm will result in a superior crop to a single application of 9 mm per day). This is a serious limitation to black carrot production under centre pivot irrigation.

- Inadequate moisture during establishment seems to be the main cause of excessive forking in black carrots. The effect may be indirect (eg. Inadequate cooling of soil physically burn roots during early development). Further work would be required to establish this.

- Forking is a more severe problem in black carrots than conventional orange varieties like Red Hot or Apache.

- Irrigation cannot be effectively managed to reduce black carrot canopy vigour while still maintaining high yields.

Plant Emergence & Establishment

Materials & Methods (BC0902 – Dareton, NSW, 2009)

Location
This trial was located at the NSW DPI Research Station near Dareton, NSW (approx: 34° 05′ 43″ S, 142° 00′ 53″ E, elevation 51 m) inside a dedicated area worked up managed solely for the purpose of conducting the trial, on a red loamy sand, typical of the region.

Design
Treatments were replicated four times in a Latin Square. Plots consisted of two pair-planted rows (4 single rows in total) on a single bed 1.6 m wide (bed centre to adjacent bed centre), 2.0m length planted of each variety/plot = 4.0m total plot length, with 2.0m buffer at each end. Beds were separated by 2.0m rather than the regular 1.6m to ensure no moisture transfer between plots.

Base Nutrition
Hifert Single Superphosphate (0:9:0 N:P:K) applied at 500kg/ha (45kg P/ha) and incorporated to 60cm with deep ripper.

Planting, Establishment & Maintenance
Trenches were dug, irrigation laid and sundry other irrigation equipment installed over several weeks in December 2008. Beds were unformed but soil was extremely free draining. Seed was first planted on 08 Jan 2009, to a depth of about 5-10 mm by marking lines for rows, creating a shallow furrow with a vee-shaped aluminium tine. Seeds were sprinkled down the furrows at approximately 4x standard seeding rates before being lightly covered by hand.

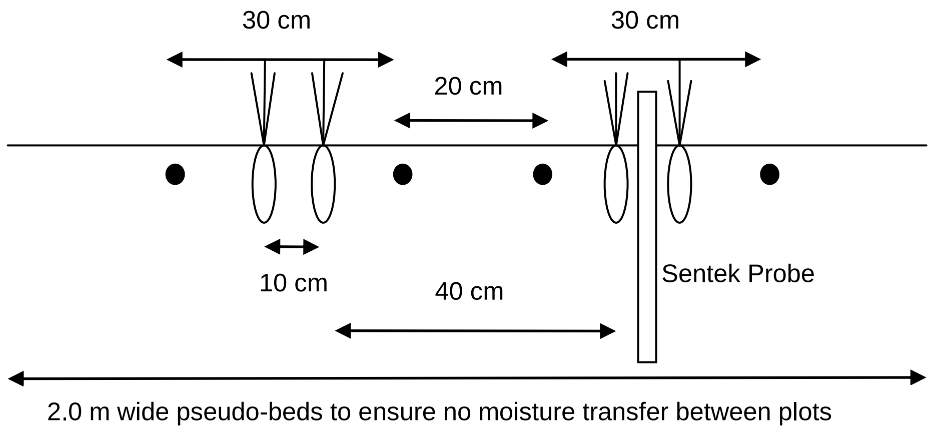
Metalxyl-m and azoxystrobin were applied as banded sprays immediately after planting, to help reduce any soil disease effects during establishment, at effective rates of 2400g ai (active ingredient)/ha & 1563gai/ha respectively. The spray was concentrated in a 10 cm wide band centred over individual seed lines, just avoiding overlap in adjacent paired rows. This gave a water volume of 1563L/ha (field) but this was effectively concentrated over only a quarter of this area (40cm of sprayed width/1.6m bed).

Linuron 500 WG + Gesagard 500 SC were applied also applied 09 Jan 2009, at 2.2kg/ha + 2.2L/ha respectively (Single jet, flat-fan knapsack sprayer at 250L/ha output).

Hortico Aquasol™ was applied at 2.0 g/m^2 09 Jan 2009. Five further fortnightly applications were made from 18 Mar 2009 to 21 Apr 2009 using a watering can and applying 20g fertilizer/8.0L water.

Irrigation
Irrigation was initially provided only by Netafim™ Uniram™ trickle tape (solid black dots) buried to about 25 mm, using 4 lines per plot as shown below:

Figure 10.1 *– BC0902: Trickle-tape Layout*



Watering was applied three times daily at 30 minutes/irrigation = 10mm/irrigation x 3/day (09:00; 13:00; 17:00 hours).

Inspection on 21 Jan 2009, showed very uneven emergence, particularly among the black carrots led to the entire trial being sprayed with glyphosate on 23 Jan 2009 & replanted 26 Jan 2009. The principle cause of this problem was not clear at the time but thought likely to be due to heat, uneven water distribution in the top 3-5 mm, herbicide damage or a combination of these.

Trickle irrigation was shut-off. To ensure even water cover in the germination zone after replanting, overhead sprinklers were installed in the area on a hexagonal grid pattern with 3.2m between risers in a line, 4.0m between irrigation lines, with risers lines alternately off-set by 1.6m. Catch tests showed the overhead sprinklers output close to 8mm/60 minutes. These were then left to apply 3 x 60 minutes daily (3 x 8mm daily) at 09:00; 13:00 & 17:00 hours.

On 19 Feb 2009, 5 Sentek EasyAG® 50 capacitance probes were installed in replicate 3 as shown, with 1 probe located between the paired rows of black carrots towards the centre of each plot and a single additional probe mounted in the same way in the reference (100%) Red Hot treatment. This allowed moisture readings to be taken at 10, 20, 30 & 50 cm soil depth and sent via cables to a solar powered data logger. Plants were hand thinned to approximately 30 mm plant spacings.

After initial readings were taken, ensuring both hardware and software were properly installed and working, the data logger was started on 11 Mar 2009. Thereafter weekly downloads were made, and based on probe readings, water was adjusted. On the same day the overhead watering was switched off and the individual trickle irrigation treatments imposed using a Toro® DDCP battery powered controller, to trip solenoids for differing durations and intervals shown in Table 10.2.

Further thinning was required 18 Mar 2009 to achieve a final plant spacing of around (29-34mm).

Trickle Tape Calibration Figures:

- Emitters were pressure compensating with a measured output very close to 1.0L/hour/emitter +/-5%. Main-line pressure was approximately 415kPa reduced to a drip-line pressure of about 80-100kPa.
- In-line emitter spacing = 200mm.
- Area covered by a single emitter was 200mm x 250mm.
- Emitter output = 1mm/3 minutes (20mm/hour).

***Figure 10.2** – BC0902: Trial Plot Design & Layout.*

West

Rep 1	Rep 2	Rep 3	Rep 4
1 RH	2 RH	3 RH	4 RH
1 B	Pr 1 2 B	3 B	4 B
2 B	Pr 2 4 B	1 B	3 B
2 RH	Pr 3 4 RH	1 RH	3 RH
3 RH	1 RH	4 RH	2 RH
3 B	Pr 4 1 B	4 B	2 B
4 B	Pr 5 3 B	2 B	1 B
4 RH	3 RH	2 RH	1 RH

South (left side of layout) / North (right side of layout)

Toro Controller, solenoids & mains

East

Rows (Beds) run East-West
RH = Red Hot
B = Black (LX3632)
Pr = Probe (Number indicated)

Probes 1-3 connect into "Run A" and probes 4-5 connect into "Run B" on Sentek Logger.
Sentek Data Logger & PV panel located between 4 RH & 1 RH in Rep 2.
Design is split plot so that both B and RH carrots for the same treatment in the same replicate are adjacent and part of the same plot (same irrigation pipes).
Probes were mounted in Replicate 3 (orange shaded above).

***Table 10.1** – BC0902: Irrigation Treatment Summary of Actual **Relative Quantities** of Water Applied (%)*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	11 Mar 2009 44 DAP	18 Mar 2009 50 DAP	25 Mar 2009 58 DAP	31 Mar 2009 64 DAP	30 Apr 2009 94 DAP	21 May 2009 115 DAP	06 Jul 2009 161 DAP
50	100	50	75	75	75	67	67
100	100	100	100	100	100	100	100
150	100	150	125	150	150	150	150
200	100	200	150	200	200	200	200

DAP = Days After Planting

***Table 10.2** – BC0902: Irrigation Treatment Summary by **Frequency & Estimated Quantities** of Water Applied (mm)*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	11 Mar 2009 44 DAP			18 Mar 2009 50 DAP			25 Mar 2009 58 DAP			31 Mar 2009 64 DAP			30 Apr 2009 94 DAP			21 May 2009 115 DAP			06 Jul 2009 161 DAP		
	F	**T**	Q	F	**T**	Q	F	**T**	Q	F	**T**	Q	F	**T**	Q	F	**T**	Q	F	**T**	Q
50	1	**36**	12	1	**12**	4	1	**27**	9	1	**27**	9	2	**27**	9	2	**12**	4	2	**8**	3
100	1	**36**	12	1	**24**	8	1	**36**	12	1	**36**	12	2	**36**	12	2	**18**	6	2	**12**	4
150	1	**36**	12	1	**36**	12	1	**45**	15	1	**54**	18	2	**54**	18	2	**27**	9	2	**18**	6
200	1	**36**	12	1	**48**	16	1	**54**	18	1	**72**	24	2	**72**	24	2	**36**	12	2	**24**	8

F = Frequency (No. of days between waterings); **T = Time (minutes)**; Q = ~Quantity of Irrigation/event (mm); DAP = Days After Planting

The 100% Original Relative Watering Treatment was the standard (reference) treatment. The quantity of water estimated for use in this treatment was based on a combination of assessments – Standard practice on this type of soil, inspections of root growth, ETo (evapotranspiration rate) and most importantly information from the capacitance probes.

Assessments

Photographs were taken over the whole cropping cycle. The trial was harvested 16 Jul 2009 (171 days after planting). 1.0 m of bed (4 rows) from the centre of each sub-plot (4 treatments x 4 replications x 2 varieties) was dug with a pitch-fork. Tops were separated and weighed on a whole sub-plot basis. All carrots were collected, washed and bagged before going into a 4°C cool store for several weeks where they remained in good condition until being sorted into shoulder width grades, and further sorted into forked or straight, before each of these categories was counted and weighed. 500 mL juice samples were extracted and anthocyanins, pH and Brix were measured at the SDS laboratory in Merbein, NSW with care taken to assess full replicate at a time.

Statistical Analyses:

In all tables shown, vertical bars aligned in the same column indicate means that are NOT SIGNIFICANTLY DIFFERENT (LSD, P=0.05). Means followed by "-" failed Bartlett's Chi-squared Test for Homogeneity of Variance and attempts to rectify this with transformations were NOT successful (P=0.05). NSAP indicates no statistical analysis performed. Blue vertical bars indicate LSD results based on successfully transformed data BUT the numbers they follow are original.

Results (BC0902 – Dareton, NSW, 2009)

***Table 10.3** – BC0902: Carrot Yield Components – Total & Harvestable Yields (t/ha)*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	TOTAL Yield (t/ha)	ORIGINAL Relative Watering Applied (%)	YIELD 21+mm (t/ha)	ORIGINAL Relative Watering Applied (%)	YIELD 26+mm (t/ha)
100% Red Hot	49.075 I	**100% Red Hot**	47.741 I	**150% Black**	46.033 I
150% Black	48.478 I	**150% Black**	47.691 I	**100% Black**	45.444 I
100% Black	48.320 I	**100% Black**	47.220 I	**200% Black**	44.127 I
200% Black	47.289 I	**200% Black**	46.263 I	**100% Red Hot**	43.020 I
50% Red Hot	46.930 I	**50% Red Hot**	45.095 I	**50% Black**	42.713 I
50% Black	46.575 I	**50% Black**	44.933 I	**200% Red Hot**	39.805 I
200% Red Hot	46.378 I	**200% Red Hot**	44.695 I	**150% Red Hot**	39.438 I
150% Red Hot	45.259 I	**150% Red Hot**	44.169 I	**50% Red Hot**	38.275 I

***Table 10.4** – BC0902: Carrot Yield Components – Total & Harvestable Yields (Numbers of Carrots)*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	TOTAL No./ha	ORIGINAL Relative Watering Applied (%)	No. 21+mm/ha	ORIGINAL Relative Watering Applied (%)	No. 26+mm/ha
200% Red Hot	870313 I	**200% Red Hot**	696875 I	**150% Black**	526563 I
50% Red Hot	867188 I	**50% Red Hot**	675000 I	**200% Red Hot**	512500 I
100% Red Hot	807813 I	**100% Red Hot**	670313 I	**100% Red Hot**	510938 I
200% Black	764063 I	**150% Red Hot**	650000 I	**200% Black**	509375 I
50% Black	762500 I	**200% Black**	618750 I	**100% Black**	493750 I
150% Red Hot	757813 I	**150% Black**	609375 I	**150% Red Hot**	481250 I
150% Black	740625 I	**100% Black**	579688 I	**50% Black**	460938 I
100% Black	728125 I	**50% Black**	571875 I	**50% Red Hot**	456250 I

***Table 10.5** – BC0902: Carrot Yield Components – Average Plant Spacing (mm) & Undersize Yields (t/ha)*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	Av. Plant Spacing (mm)	ORIGINAL Relative Watering Applied (%)	YIELD <21mm (t/ha)	ORIGINAL Relative Watering Applied (%)	YIELD 21-25mm (t/ha)
100% Black	34.4 I	**50% Red Hot**	1.997 I	**50% Red Hot**	6.658 I
150% Black	33.8 I	**200% Red Hot**	1.683 I I	**200% Red Hot**	4.891 I
50% Black	33.4 I	**50% Black**	1.480 I I I	**150% Red Hot**	4.731 I
200% Black	33.0 I	**100% Red Hot**	1.334 I I I	**100% Red Hot**	4.720 I
150% Red Hot	33.0 I	**100% Black**	1.100 I I	**50% Black**	2.383 I
100% Red Hot	31.0 I	**150% Red Hot**	1.091 I I	**200% Black**	2.136 I
200% Red Hot	29.1 I	**200% Black**	1.027 I I	**100% Black**	1.777 I
50% Red Hot	28.9 I	**150% Black**	0.788 I	**150% Black**	1.658 I

***Table 10.6** – BC0902: Carrot Yield Components – Undersize Yields (Numbers of Carrots)*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	No. <21mm/ha	ORIGINAL Relative Watering Applied (%)	No. 21-25mm/ha
200% Red Hot	870313 I	200% Red Hot	696875 I
50% Red Hot	867188 I	50% Red Hot	675000 I
100% Red Hot	807813 I	100% Red Hot	670313 I
200% Black	764063 I	150% Red Hot	650000 I
50% Black	762500 I	200% Black	618750 I
150% Red Hot	757813 I	150% Black	609375 I
150% Black	740625 I	100% Black	579688 I
100% Black	728125 I	50% Black	571875 I

***Figure 10.3** – BC0902: Carrot Yield Components – Total & Harvestable Yields (t/ha), classified by* Original Relative Watering Applied (%)

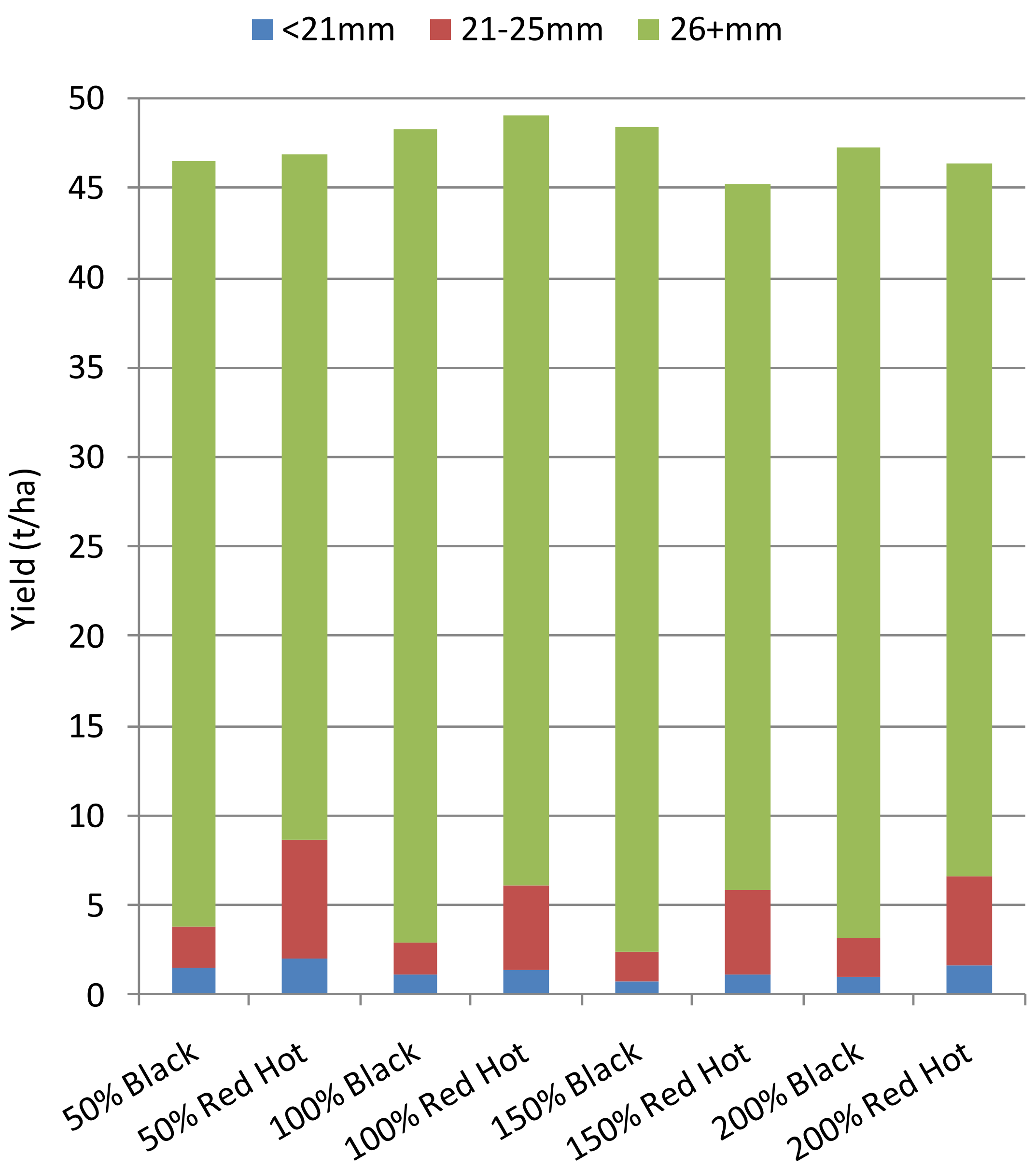


***Table 10.7** – BC0902: Canopy Yield Components – Canopy Yields (t/ha) & Canopy/Carrot Yield Ratios*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	Canopy Yield (t/ha)	ORIGINAL Relative Watering Applied (%)	Canopy/ Carrot Weight Ratio
100% Black	21.277 I	**100% Black**	0.44 I
200% Black	19.469 I	**200% Black**	0.42 I
50% Black	17.322 I	**50% Black**	0.37 I
150% Black	16.820 I	**150% Black**	0.34 I
100% Red Hot	9.777 I	**100% Red Hot**	0.20 I
150% Red Hot	8.506 I	**150% Red Hot**	0.19 I
50% Red Hot	8.469 I	**50% Red Hot**	0.18 I
200% Red Hot	8.305 I	**200% Red Hot**	0.18 I

***Figure 10.4** – BC0902: Total Plant, Carrot & Canopy Yields (t/ha), classified by* Original Relative Watering Applied (%)

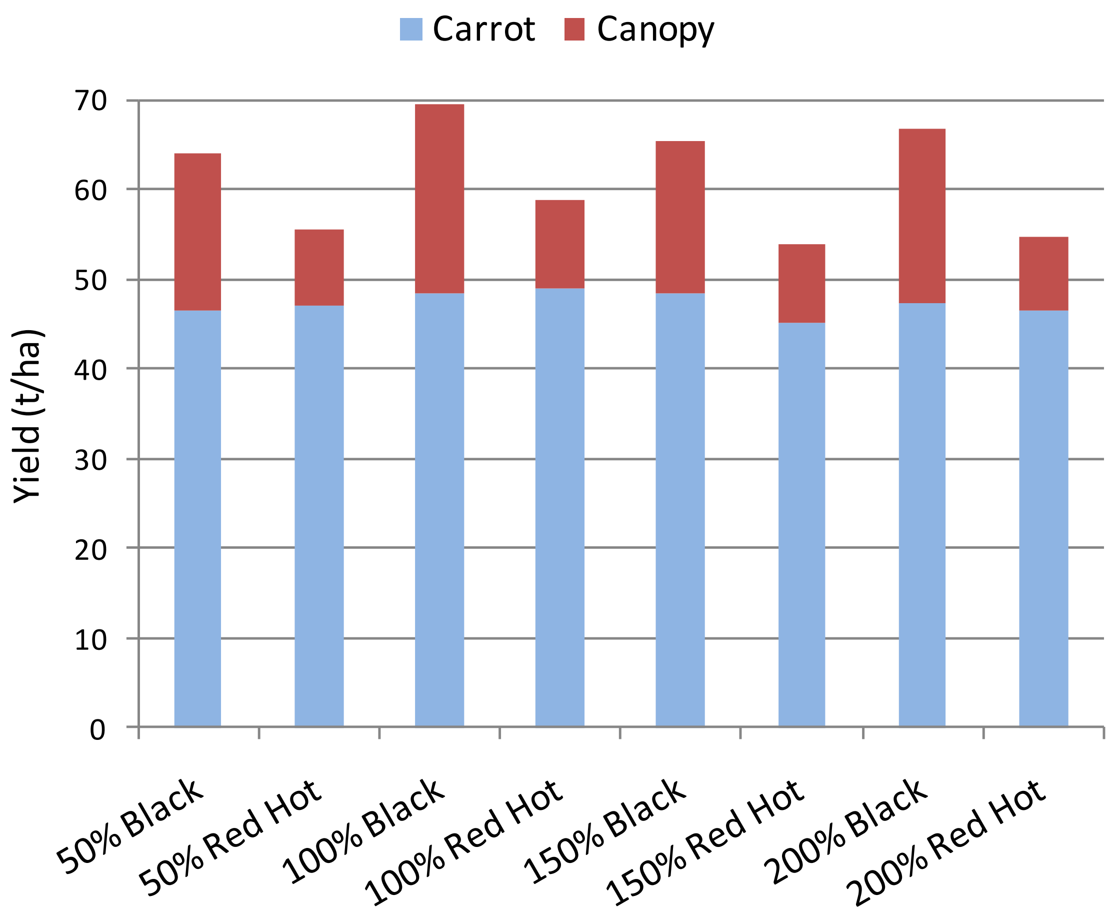


***Table 10.8** – BC0902: Average Carrots Weights based on Total & Harvestable Yields (g)*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	Av. Carrot Weight for Total Yield (g)	ORIGINAL Relative Watering Applied (%)	Av. Carrot Weight for Carrots 21+mm (g)	ORIGINAL Relative Watering Applied (%)	Av. Carrot Weight for Carrots 26+mm (g)
100% Black	66.4 I	**100% Black**	81.6 I	**50% Black**	93.6 I
150% Black	65.6 I	**50% Black**	80.5 I	**100% Black**	92.7 I
200% Black	62.7 I	**150% Black**	78.3 I I	**150% Black**	87.4 I
50% Black	62.3 I	**200% Black**	74.7 I I	**200% Black**	86.3 I
100% Red Hot	61.0 I	**100% Red Hot**	71.2 I I	**100% Red Hot**	84.4 I
150% Red Hot	59.9 I	**150% Red Hot**	68.1 I I	**50% Red Hot**	82.9 I
50% Red Hot	54.7 I	**50% Red Hot**	66.5 I I	**150% Red Hot**	81.4 I
200% Red Hot	53.2 I	**200% Red Hot**	63.8 I	**200% Red Hot**	77.2 I

***Table 10.9** – BC0902: Total & Harvestable Yields of **Forked** Carrots*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	Total FORKED Yield (t/ha)	ORIGINAL Relative Watering Applied (%)	FORKED Yield 21+mm (t/ha)	ORIGINAL Relative Watering Applied (%)	FORKED Yield 26+mm (t/ha)
200% Black	21.973 I	**200% Black**	21.950 I	**200% Black**	21.598 I
100% Black	19.503 I I	**100% Black**	19.439 I I	**100% Black**	19.061 I I
50% Black	17.339 I I	**50% Black**	17.300 I I	**50% Black**	16.905 I
150% Black	16.620 I	**150% Black**	16.586 I	**150% Black**	16.464 I
50% Red Hot	3.894 I	**50% Red Hot**	3.870 I	**50% Red Hot**	3.784 I
100% Red Hot	3.391 I	**100% Red Hot**	3.334 I	**150% Red Hot**	3.041 I
150% Red Hot	3.250 I	**150% Red Hot**	3.234 I	**100% Red Hot**	3.013 I
200% Red Hot	3.055 I	**200% Red Hot**	2.973 I	**200% Red Hot**	2.606 I

***Table 10.10** – BC0902: Total & Harvestable Yields of **Straight** (Unforked) Carrots*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	Total STRAIGHT Yield (t/ha)	ORIGINAL Relative Watering Applied (%)	STRAIGHT Yield 21+mm (t/ha)	ORIGINAL Relative Watering Applied (%)	STRAIGHT Yield 26+mm (t/ha)
100% Red Hot	45.684 I	**100% Red Hot**	44.406 I	**100% Red Hot**	40.008 I
200% Red Hot	43.323 I	**200% Red Hot**	41.722 I	**200% Red Hot**	37.198 I I
50% Red Hot	43.036 I	**50% Red Hot**	41.063 I	**150% Red Hot**	36.397 I I
150% Red Hot	42.009 I	**150% Red Hot**	40.934 I	**50% Red Hot**	34.491 I I I
150% Black	31.858 I	**150% Black**	31.105 I	**150% Black**	29.569 I I I
50% Black	29.236 I	**50% Black**	27.795 I	**100% Black**	26.383 I I
100% Black	28.817 I	**100% Black**	27.781 I	**50% Black**	25.808 I I
200% Black	25.316 I	**200% Black**	24.313 I	**200% Black**	22.528 I

Figure 10.5 *– BC0902: Total Straight & Forked Yields (t/ha), classified by* Original Relative Watering Applied (%)

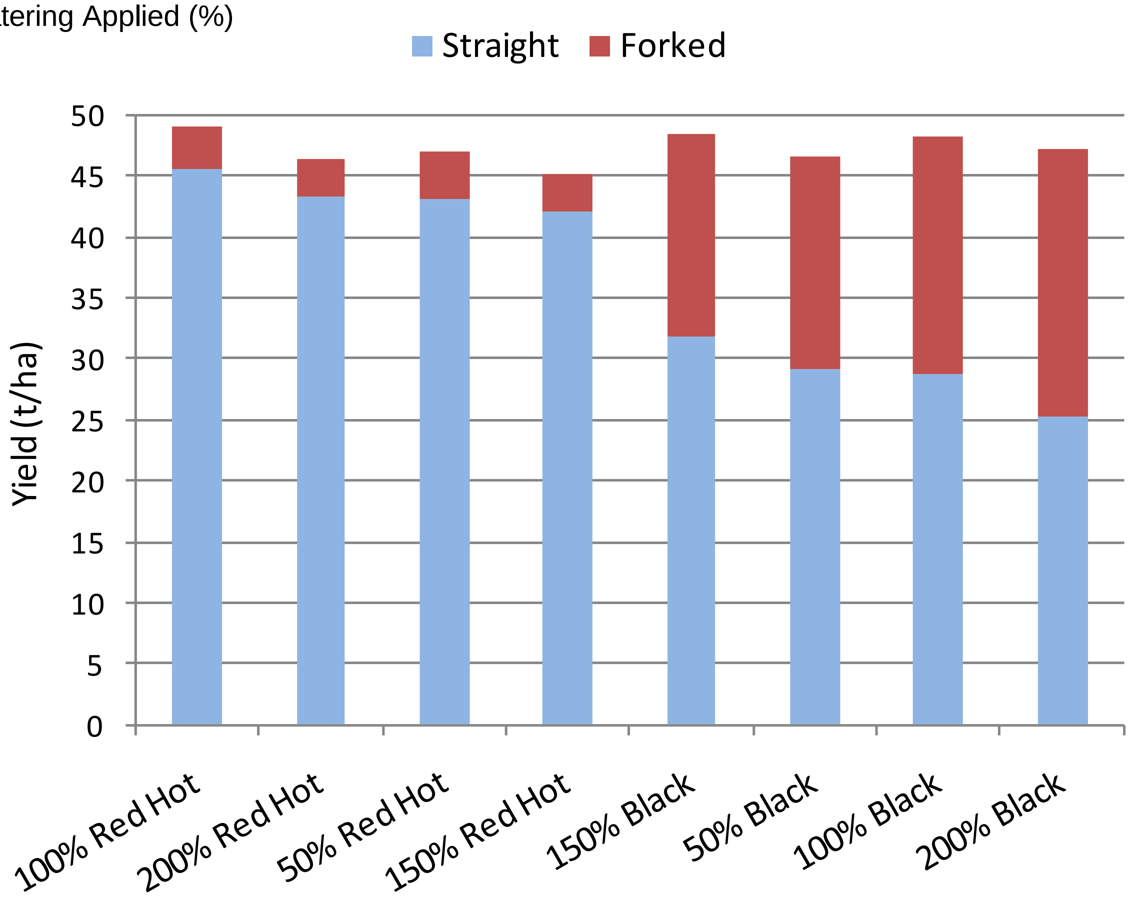


Table 10.11 *– BC0902: pH & Brix (°Br)*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	pH	ORIGINAL Relative Watering Applied (%)	Brix (°Br)
50% Red Hot	6.14 I	**50% Black**	10.6 I
150% Red Hot	6.13 I	**200% Black**	10.4 I
100% Red Hot	6.13 I	**100% Black**	10.4 I
200% Black	6.11 I	**150% Black**	10.4 I
200% Red Hot	6.11 I	**50% Red Hot**	9.6 I
50% Black	6.10 I	**150% Red Hot**	9.6 I
100% Black	6.09 I	**100% Red Hot**	9.6 I
150% Black	6.07 I	**200% Red Hot**	9.5 I

Table 10.12 *– BC0902: Absorbance (@538nm) & Anthocyanins (mg%@8.0°Br)*, classified by Original Relative Watering Applied (%)

ORIGINAL Relative Watering Applied (%)	Absorbance (@538nm)	ORIGINAL Relative Watering Applied (%)	Anthocyanins (mg%@8.0°Br)
50% Black	0.952 I	**50% Black**	98.8 I
200% Black	0.835 I	**200% Black**	85.8 I
100% Black	0.825 I	**100% Black**	84.0 I
150% Black	0.745 I	**150% Black**	76.5 I

Capacitance Probe Records
In Figures 10.6-10.10, the depth readings are shown by the first number on the LHS of the vertical axis of the figure and are as follows: 1 = 10cm; 2 = 20cm; 3 = 30cm; 4 = 50cm. The soil water content is indicated in mm.

Figure 10.6 *– BC0902:* ***50%*** *Original Relative Watering Black Carrots (Rep. 2) - Capacitance Probe Moisture Record 11 Mar 2009 – 16 Jul 2009*

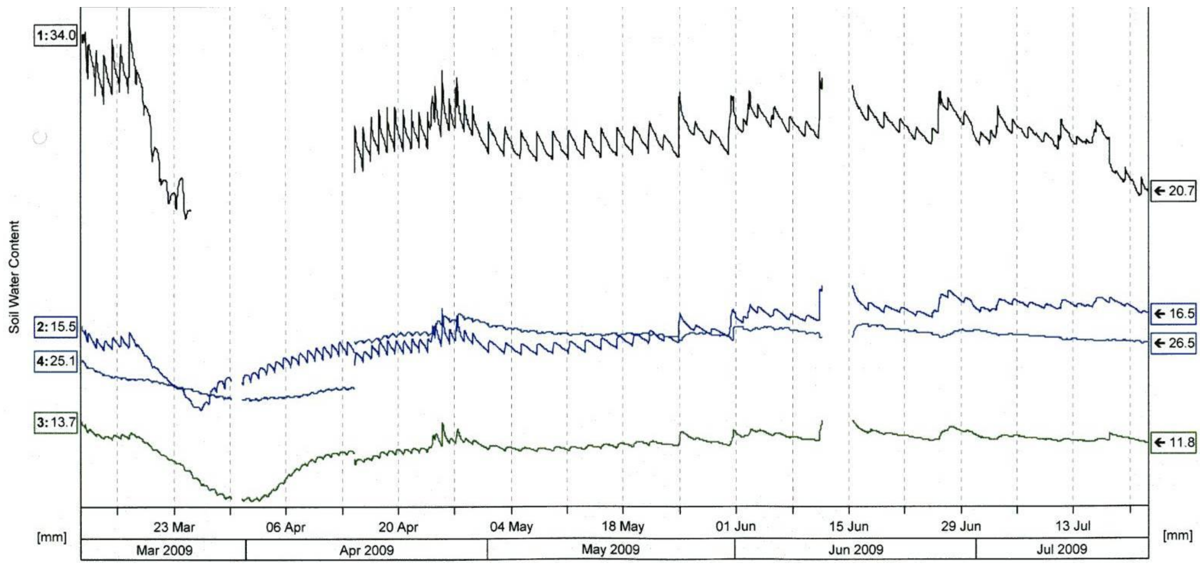


Figure 10.7 *– BC0902:* ***100%*** *Original Relative Watering Black Carrots (Rep. 2) - Capacitance Probe Moisture Record 11 Mar 2009 – 16 Jul 2009*

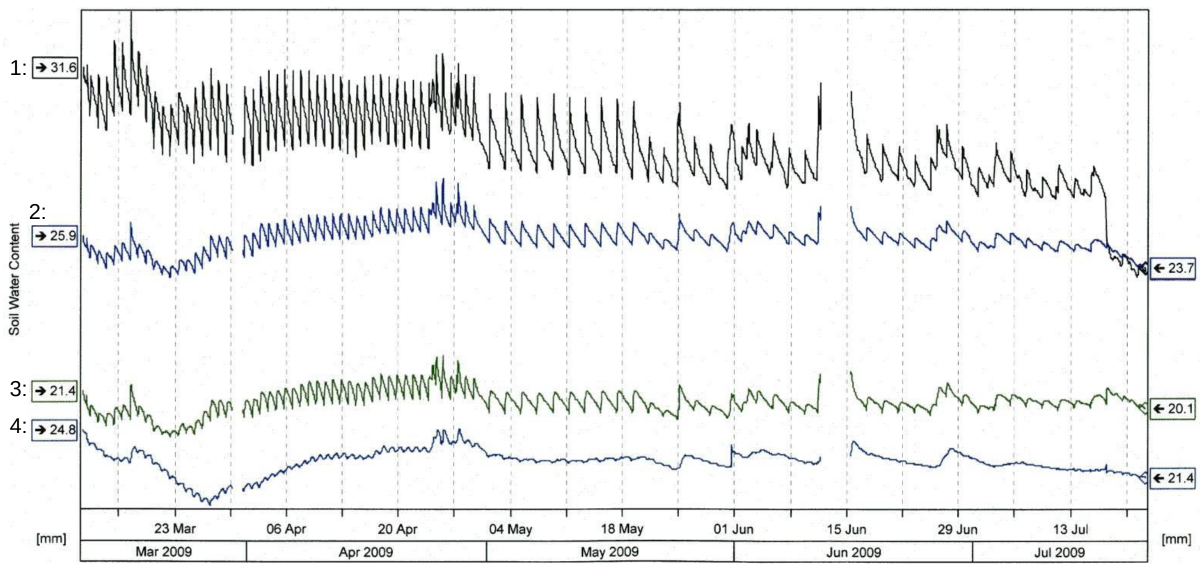


Figure 10.8 *– BC0902:* ***100%*** *Original Relative Watering* ***Red Hot*** *Carrots (Rep. 2) - Capacitance Probe Moisture Record 11 Mar 2009 – 16 Jul 2009*

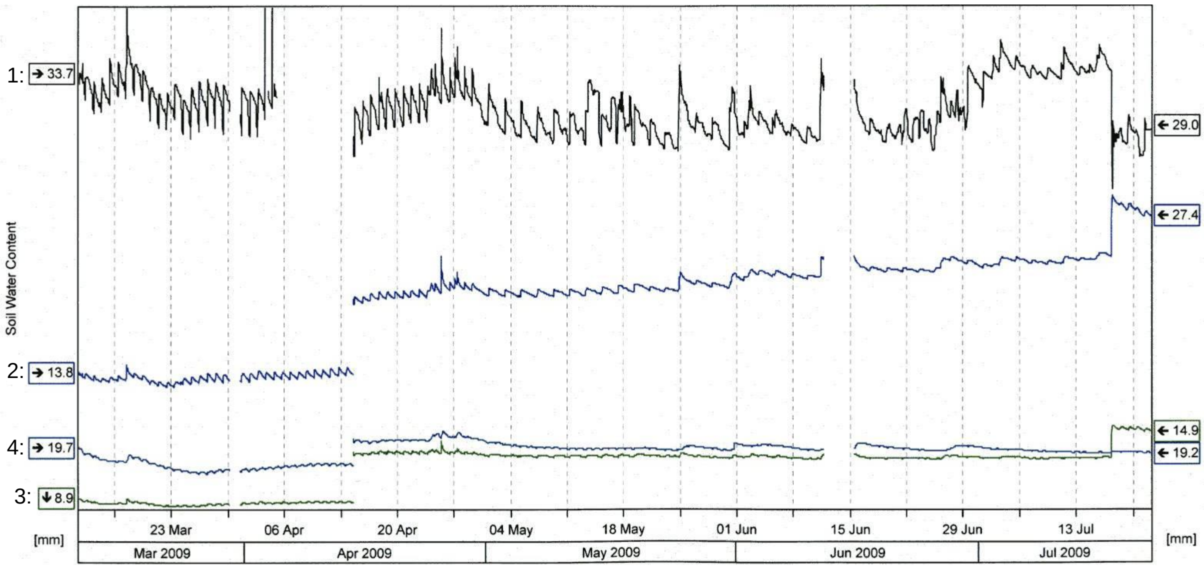


Figure 10.9 *– BC0902:* ***150%*** *Original Relative Watering Black Carrots (Rep. 2) - Capacitance Probe Moisture Record 11 Mar 2009 – 16 Jul 2009*

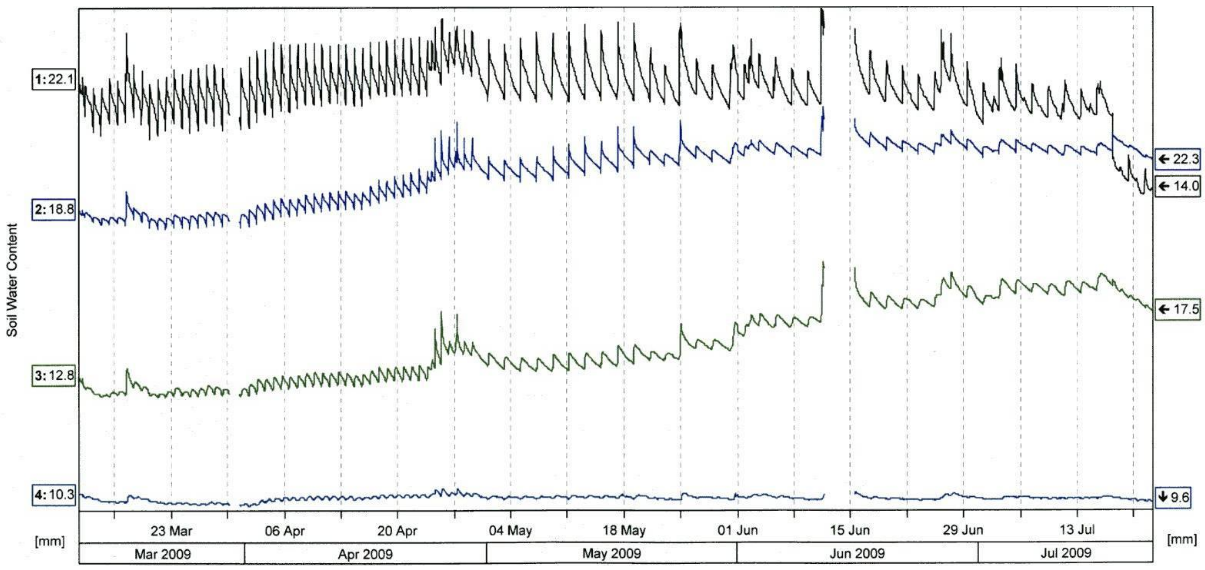


***Figure 10.10** – BC0902: **200%** Original Relative Watering Black Carrots (Rep. 2) - Capacitance Probe Moisture Record 11 Mar 2009 – 16 Jul 2009*

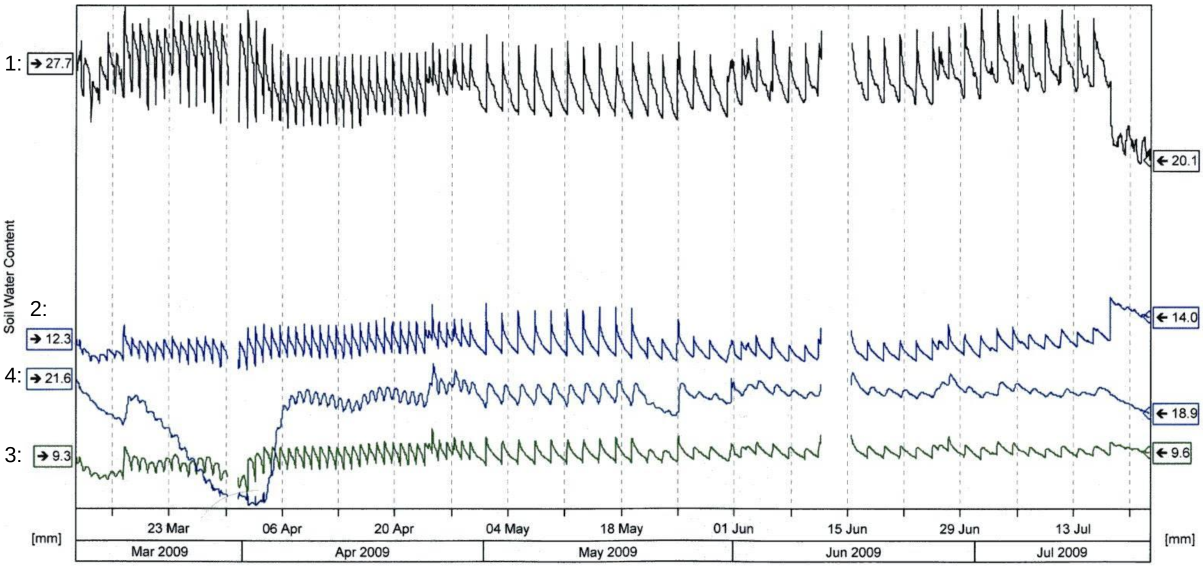


***Photo 10.1** – BC0902: Complex installation, required four separate controllers providing four independent watering lines to the four different treatments.*

Photo 10.2 *– BC0902: Each of the four main lines provided water to a single plot in each of the four replications.*

Photo 10.3 – *BC0902: Each plot was watered by four drip lines. Note the closest plot has yet to be buried. The three other plots from the same treatment can be seen as the wet plots.* Main line trenches have yet to be filled in.

Photo 10.4 *– BC0902: Seed furrows in relation to drippers just prior to being seeded and covered.*

Photo 10.5 *– BC0902: 115 days after planting. Alternating ends of plots for Red Hot (short) & LX3632 (tall). Capacitance probes in Rep. 2, where data logger is also mounted.*

Discussion (BC0902 – Dareton, NSW, 2009)

General

The key outcomes were:

- The 50% regime still delivered adequate moisture to maximize yield and quality.
- LX3632 achieved similar total & harvestable yields to Red Hot given adequate moisture. However, a much higher proportion of the black carrot yield was forked.
- LX3632 forked much more severely than Red Hot.

Probe Outputs and Watering Regimes Used (Figures 10.6-10.10)

Examination of these shows the difficulties as well as the benefits arising from the use of soil capacitance probes.

Figures 10.6 & 10.8 show sensor problems that required repairs. All probes show short periods of missing data over several days in late March and again in mid-June. The exact cause of the latter events was not identified but likely a temporary circuit shorting somewhere caused by water entering part of the equipment meant to be sealed to prevent such things happening.

The steady decline in moisture levels in mid-late March shown with sensor 4 in Figure 10.10 & most of the sensors in Figures 10.6 & 10.7 are also aberrations. The irrigation equipment was known to be functioning well at this time and the same decline is not seen in Figure 10.8 & 10.9.

The probe in the 100% Red Hot plot (Figure 10.8) required full reinstallation as indicated by the change in magnitude of the output in mid-April.

Individual depth records only give moisture information that can be directly related to other depth records from the same probe (treatment). While the probes were all installed within several metres of each other, differences in soil permeability are indicated. Figures 10.7 & 10.8 for example which show the standard 100% regime for black & Red Hot carrots respectively, also show differences in profile permeation despite being in the same plot and only 4m apart. This underscores the importance for growers to have multiple probes covering the range of soil profiles present in any paddock being monitored.

Irrigation decisions were based on the depth to which the different treatments had an effect. Irrigation time settings aimed to achieve:

- Little change in moisture at 30-50cm in with the 50% treatment.
- Irrigation affecting moisture at 30cm in the 100% treatment(s).
- Fluctuating moisture at 50 cm with the 200% treatment corresponding to irrigation events being applied.

Total & Harvestable Yields by Weight (Table 10.3)
There were no significant treatment differences associated with irrigation treatments applied. This was true whether total yield or harvestable yield based on a 21mm or 26mm minimum shoulder width was imposed. This is the first trial undertaken showing comparable or even superior yields from black carrots than from a standard orange type. That said, these were not especially impressive Red Hot yields by commercial standards.

Total & Harvestable Yields by Number (Table 10.4)
Bearing in mind these carrots were hand-thinned to similar densities, no differences in total or harvestable yields based on numbers of carrots were significant.

Average Plant Spacing & Undersize Yields by Weight (Table 10.5)
Again, as plots were hand thinned, a similar average spacing was expected and the results bear this out, showing no significant differences could be attributed to differences in plant spacing.

While there were significant differences in <21mm yields, no differences could be attributed to irrigation effects. On balance Red Hot showed higher yields of this size category.

Red Hot showed significantly higher yields of 21-25mm carrots than LX3632 but differences were not related to irrigation treatments.

Undersize Yields by Number (Table 10.6)
There were no significant differences in <21mm numbers. On balance Red Hot showed higher numbers of this size category.

No differences between irrigation treatments were significant but all Red Hot treatments showed more carrots in the in 21-25mm category.

Yield – All Components Summed by Weight (Figure 10.3)
This figure shows consistently higher yields of carrots <26mm for Red Hot than for black carrots as a proportion of total yield, but no effects from irrigation.

Canopy Yields & Canopy/Carrot Weight Ratios (Table 10.7 & Figure 10.4)
Canopy yields and Canopy/Carrot ratios were significantly higher for all black carrot treatments than for Red Hot treatments. Irrigation had no effect on canopy yield or the Canopy/Carrot yield ratio.

Average Carrot Weights for Total & Harvestable Yields (Table 10.8)
All black carrot treatments showed higher average carrot weights for both total and harvestable yields, though the differences were not always significant. Irrigation has no effect on average carrot weight.

Forked & Straight Total & Harvestable Yields (Tables 10.9-10.10 & Figure 10.5)
All black carrot treatments showed significantly higher yields of forked carrots (around 5 times the yield) than Red Hot. This was true for total and harvestable yields.

All Red Hot treatments showed significantly higher yields of straight carrots (around 1.5 times the yield) than black treatments. This was true for total and harvestable yields.

No effects were related to irrigation.

Brix, pH, Absorbance & Anthocyanin Content (Tables 10.11 & 10.12)
Brix levels were consistently and significantly higher for black carrots than for Red Hot. This was the only trial conducted over the course of the project where this was found.

Anthocyanin and pH differences were not significant and irrigation had no effect.

Bolting
There was no early bolting but by 171 days after planting and sufficient winter cold, very occasional plants were beginning to bolt. This was the trigger for harvest but no yield adjustments were required to account for this factor.

Nutrient Use & Removal
Foliar and carrot nutrient analysis from this trial was used to calculate approximate nutrient removal by the crop (Section 5).

Additional Data

Table 10.13 compares yields & average carrot weights for both LX3632 & Red Hot (Apache) from several trial sites where both crops were planted at the same time alongside each other, and relates these to amounts of watering applied and relative rates of evapotranspiration (based on location, humidity and planting time).

The main features are reduced **relative** yields and average carrot weights for LX3632 compared with Red Hot as readily available soil moisture in the critical first 4-6 weeks after planting declines.

Table 10.12 *– BC0706, BC0805, BC0901 & BC0902: Average Weights, Total & Harvestable Yields, related to Soil Moisture status in the first 4-6 weeks after Planting*

Trial	Variety	Daily Watering Applied	Relative Rate of Evapotranspiration	Average Weight (g)	Total Yield (t/ha)	Harvestable Yield 26+mm (t/ha)
BC0902 Dareton NSW	LX3632	3 x 8mm during hottest 8 hours	High	64	47.7	44.6
	Red Hot			57	46.9	40.1
BC0706 Clyde Victoria	LX3632	1 x 10 mm various times	Low-Medium	74	48.7	48.4
	Red Hot			95	62.5	62.1
BC0901 Clyde Victoria	LX3632	1 x 10 mm various times	Medium-High	55	34.4	31.5
	Red Hot			77	60.1	54.2
BC0805 Parilla SA P1 & 2	LX3632	1-2 x 4 mm various times	Medium-High	67	63.2	50.7
	Red Hot			147	108.0	104.7
BC0805 Parilla SA P3	LX3632	2 x 4 mm various times	High	36	38.2	28.5
	Red Hot			80	45.2	37.0

11 Technology Transfer

As a VC project, SDS Beverages was to have a limited period of exclusive access to the data and key findings in this report. Specific results were not published in magazines or other industry publications.

The intention was to disseminate key findings among growers growing black carrots exclusively for SDS. However, no commercial crops were produced by growers for SDS over the life of this project, prior to SDS going into receivership in 2009.

AHR took over the VC payment to HAL for the project from the time SDS went into receivership. SDS were in arrears in their VC payments prior to going into receivership and AHR made these payments to HAL as well. The new owners of SDS bought the equipment, not the business and have certainly not made any payments to AHR in regard to unpaid VC payments for the project. In view of this situation, AHR would like to retain the original agreement and keep the results confidential for 12 months from the end of the project and during this time, attempt to gain some commercial advantage from the investment. After the 12-month embargo, the full results will be publicly released.

A general presentation on the kinds of areas investigated in the project was given at the Root Vegetable Think Tank conducted by Arris in Adelaide 19-20 April 2010.

A short paper is to be presented at the ISHS Conference in Lisbon, Portugal in August 2010 based on a trial that demonstrated a relationship between bolting and plant density.

SDS were kept informed about key activities and findings, with AHR providing updates to Simon Fethers every few weeks. There were formal meetings that included Excelfresh in addition to SDS during the project covering key events and findings.

All trials conducted on commercial farms were discussed with relevant growers. Specific results from trials on their own farm were presented to Parilla Premium Potatoes, who had previously grown black carrot crops for SDS and were key co-operators during the project.

The main findings and the Agronomic Guide will be key platforms for technology extension as soon as this report can be released. The Agronomic Manual will be made available on the AHR website after the 12-month embargo. There will also be a link to HAL's website for those wishing to obtain a copy of the main report. AHR are also willing to provide electronic copies of the report to growers or industry groups HAL may wish it to be available to.

12 Recommendations

General

The progress of this fledgling industry has suffered a significant setback with the major processor (SDS Beverages) going into receivership. However, the factory has recently been acquired by Rocky Lamattina & Sons P/L. Re-establishing conventional high carotene juice concentrate is currently the new owner's main priority. However, it is hoped that within 12 months, the findings and recommendations from this report might help revitalize the black carrot industry in that region. Meanwhile, there has been steady progress over the last 6 months or so in establishing a highly profitable, albeit small scale nutraceutical industry using black carrots.

This project has clearly identified the main agronomic difficulties that have hitherto made black carrot production unattractive to growers and to the extent that current genetics will allow, devised a set of critical guidelines to address these difficulties. With a steady increase in public awareness of the health benefits associated with consuming black carrots, there are good prospects for an increase in local consumer demand and therefore an increase in the price of carrots destined for this market. Should this occur, this project will provide the kind of information that both producers and processors can make immediate use of to establish a fair market price for a certain yield and level of product quality. It will also help to avoid the mistakes commonly made in the past which have so often resulted in disappointing crops and deterred growers from committing to ongoing black carrot production.

Optimum Harvest Maturity for Black Carrots

- For processing, the ideal harvest maturity for LX3632 is likely to occur around 140-160 days after planting. Further work to fine tune this for different regions would be of value. Growers should use the onset of leaf senescence (about 1-5%) as a guide to full maturity being achieved and begin digging anytime after 140 days if there are any indications of late bolting beginning.

- Harvesting too early (typically 130 days or earlier) is likely to prevent Brix, anthocyanins and yield from reaching full potential.

- Harvesting too late (typically 170 days or later) runs the risk of late bolting and decreased foliage for harvesters to grip while lifting. However, it is unlikely to reduce Brix or anthocyanin levels. Yield may be reduced by rots, if harvested too late particularly if grown in warm northern climates.

- The most effective means currently identified for maximizing anthocyanins is to allow carrots to fully mature (140-160 days).

Modelling, Predicting & Reducing Bolting in Black Carrots

Over the life of the project, bolting in the Excelfresh black carrot variety **LX3632** was found to follow one of two distinct pathways:

3. **"Late" Bolting**: Plants remain in vegetative growth for about 150-170 days before bolting is evident.

4. **"Early" Bolting**: Evidence of bolting can be seen by about 50-60 days.

NO crops were found to bolt in the intermediate period (between about 60 & 150 days). This suggests a relatively distinct threshold requirement for cold exposure during the first few weeks of crop development to either trigger immediate bolting or to commit to a long vegetative period.

Crops that did not receive adequate early cold exposure to early bolt would then remain vegetative for 150-170 days. This occurred regardless of how much subsequent exposure to vernalizing cold the crop experienced. This is the desired path for commercial carrot crops (non-seed crops).

Using the three cardinal temperatures for bolting (T_{base} = -1°C;$T_{optimum}$ = 6.5°C; $T_{maximum}$ = 16°C), thermal time (Cd) was defined as the level of exposure to an average day temperature less than 16.0°C, summed for the days in the first 21-28 days using an equation devised by Craigon *et al* in 1990 (details - next page).

An examination of the occurrence (or not) of early bolting in some 30 studies, showed:

- Exposure to NOT MORE THAN 3.0° Cd in the first 3 weeks or 4.1° Cd in the first 4 weeks did NOT trigger "early" bolting.
- Exposure to AT LEAST 7.9° Cd in the first 3-4 weeks was sufficient to trigger "early" bolting.
- The critical period of exposure to vernalizing temperatures leading to early bolting in LX3632 may be no longer than the first fortnight after planting but this needs confirmation through further work.

There were rare contrary results that did not fit this model. Until further refined, **this model should only be used as an indicative guide** for determining safe sowing dates to avoid bolting. Other factors may also affect or modify this model.

Prospective LX3632 growers can obtain a Microsoft® Excel® template of the model from AHR for live or historic climate data entry, to calculate the likelihood of significant bolting.

A broad, more practical guideline proposed given the sensitivity to any exposure to daily average temperatures below 16°C is:

"Avoid planting LX3632 if there are likely to be ANY daily average temperatures below 16.0°C in the first four weeks after planting".

Optimum Planting Densities for Black Carrots

For the Excel Fresh variety LX3632, a 10/40/10 configuration (see Section 2 – General Materials and Methods), on 1.63 metre centred beds:

- Based on all trials, a 40-**50**mm plant spacing (with a preference towards the wider end of this range) appears to be the ideal plant spacing for this variety balancing yield and average carrot size.
- 30-35mm spacings between plants (~714,000–833,000 plants/ha) achieved the highest yield of harvestable carrots, using either a 21 or 26 mm minimum shoulder

(crown) width. However, the average weight of harvestable carrots was low (74-81 g at 21 mm minimum width and 87-95 g at 26 mm minimum width).

- **50 mm spacings** between plants (500,000 plants/ha) achieved a higher average harvestable carrot weight of 100 g at 21 mm and 111 g at 26 mm. The yield trade-off required to achieve this was not significant.

- Plant density significantly affected the population frequency of bolting, with significantly higher levels of bolting at lower plant densities.

These densities are likely to apply to other row and bed configurations, particularly the 7/27/7/27/7 configuration using 3 paired rows on 1.6 metre bed centres.

These figures should help a processor make decisions that balance the trade-off between yield and average carrots size (weights) and through this, recommendations to growers about the preferred establishment density.

Important Note: The above figures refer to targeted plant establishment densities NOT seeding densities which will be higher and vary with seed viability and survival in the field.

Using very high seeding densities (resulting in plant spacings less than 25 mm) to overcome poor seed viability is NOT effective. While total yields were high, harvestable yields were very poor and stands did not self-thin to the extent required to counter over-rate sowing.

Manipulating plant density is NOT an effective way of controlling canopy vigour. Although the canopy/carrot weight ratio increases as plant spacing increases, the change is small and carrot yield alone is a much more important consideration. Larger carrots are associated with larger tops and higher yields of carrots are associated with higher canopy weights.

Plant density does not significantly affect pH, Brix or anthocyanin content per unit weight of harvested material.

Identifying Key Nutritional Requirements & Manipulating Black Carrot Canopy Volume

For Excel Fresh variety LX3632:

- Manipulating crop available nitrogen is neither reliable nor effective for altering the partitioning of crop photosynthates away from shoot into root development.

- Black carrots are very insensitive to surplus nitrogen and showed no clear tendency to use it for extra shoot or root growth. This is consistent with previous studies in more conventional orange carrots.

- High black carrot yields require large canopies.

- Black carrots appear to be very effective nutrient “scavengers”, particularly of N & P, capable of growing well even when soil nutrient levels (referenced for standard carrots) indicate marginal availability or even deficiencies.

- Black carrot yield and quality is very poorly correlated to nutrition levels applied. There appear to be a number of other more important soil factors such as drainage and moisture availability that influenced yield more than nutrition in the normal range (extreme deficiencies and excesses did not occur).

- Reference (Guide) foliar nutrient levels for black carrots are likely to be somewhat lower than for ordinary orange carrots. Foliar nutrient levels in black carrots are very dependent on the vigour of material sampled. Larger, greener canopies have shown greater nutrient dilution than smaller, often yellower material. Leaf nutrient levels in black carrots leaves are often found to be lower than in Red Hot carrots grown in the same trial, because of the same growth dilution seen in the larger canopies of black carrots.

- Back carrot nutrition should generally follow standard carrot recommendations for the areas they are being grown in. LX3632 & Red Hot typically use similar amounts of nutrients/ha when grown under similar conditions. The canopy represents about 28-42% of total crop weight in black carrots (LX3632) but only about 16-22% of the total crop weight in Red Hot. As most nutrients are found in higher concentrations in the leaves than in the carrots, LX3632 takes up considerably more of most nutrients than Red Hot per tonne of total plant weight and even more per tonne of carrot yield. Total yields of LX3632 are typically only about 60% of Red Hot under similar conditions.

- Black carrots require a steady supply of N, P, K, Cu, Mn & Zn for the duration of the cropping cycle with no specific periods of peak demand. Adequate P& K for the whole cropping cycle should be made available in a base fertilizer at planting. N is best supplied steadily throughout the season to avoid leaching and denitrification losses. Cu, Mn & Zn need to be monitored and applied any time foliar levels become marginal.

From the main trial:

> The key period for S & B demand is 0-6 weeks after planting. These nutrients should be sufficiently available in the soil or supplemented in base fertilizer at planting.
>
> The key period for Ca, Mg & Mo demand is 6-10 weeks after planting.
>
> The key period for Fe demand is 10-21 weeks after planting.

- From harvested tissue (carrots and tops) calculations, a 35-50 t/ha crop of black carrots uses approximately 240-402kg K/ha, 69-193kg N/ha, 100-136kg Cl/ha, 39-65kg Ca/ha, 21-36kg P/ha, 13-16kg S/ha, 11-13.5kg Mg/ha, 373-761g Fe/ha, 183-310g B/ha, 160-346g Zn/ha, 149-225g Mn/ha, 22-46g Cu/ha & 1.8-7.4g Mo/ha.

- Many of the most suitable production regions are on sandy soils which also tend to be very deficient in a range of minor and trace elements. Particular attention needs to be paid to addressing known trace element deficiencies. Trace element deficiencies were more likely to be the cause of poor yields in these studies than major element deficiencies which were nearly always found at adequate to high levels in these studies.

Canopy Manipulation using Chemical Plant Growth Regulators

NB: NO Plant growth regulators, including paclobutrazol, are currently registered for use in carrots in Australia.

- For reducing canopy volume, black carrots are most responsive to plant growth regulator products in early development (6 weeks after planting) and less responsive as plants mature (12 weeks or later).

- Paclobutrazol (Payback®) has been shown to be highly effective at reducing canopy growth when applied 6 weeks after planting. However, there is evidence that at 1250g ai (active ingredient)/ha paclobutrazol also reduces carrot weights and yields. This rate proved excessive and further, more detailed evaluation would be required to develop a suitable program for use rates and application timing(s). Nonetheless it does prove canopy volume can be manipulated with at least one growth regulator product.

Evaluation of New Anti-oxidant Carrot Varieties

Excel Fresh variety LX3632 remains the preferred high anthocyanin cultivar for processing. The detailed reasons for this are outlined below:

Prospective New Black Carrot Production Regions

- Production of LX3632 in traditional southern Australian growing regions remains tightly constrained by the carrot's extreme sensitivity to early bolting. On current indications, at best this is a 2-3 month window covering the hottest period of the year.

- Northern production regions offer a significant extension to the currently constrained planting periods for traditional southern production. If crop value can justify freight costs, there are sufficient suitable locations in mainland Australia for year-round production of LX3632.

- The northern limit to successful LX3632 production lies in regions with a climate similar to or intermediate between Katherine and Bowen. Darwin was found to be unsuitable.

- Brix and anthocyanin production from northern region crops appears to be at least comparable with southern crops. High yields and average carrot weights seem to be the biggest challenge or at least warrant further work to clarify the suitability of northern region production.

- A number of other prospective production regions in mainly coastal Queensland offer the most likely path to scheduled cool season production of LX3632.

- The Mallee regions of SA, Victoria and NSW represent the southernmost production regions for LX3632. While some crops were successfully grown without significant bolting at the hottest time of the year in southern (coastal) Victoria, climate is marginal and the planting window restricted to not more than about 4 weeks.

- Tasmania is unsuitable for production of LX3632 as average day temperatures are likely to induce bolting at all times of the year.

- Caution is recommended in southern regions for late summer – early autumn plantings. Inadequate early accumulation of heat units often results in poor, low yielding crops even if heat in the first 3-4 weeks is sufficient to prevent early bolting.

Black Carrot Tolerance to the Herbicides Linuron & Prometryn

- LX3632 tolerates pre-emergent applications of linuron and prometryn similarly to conventional orange carrots. Growers should apply these herbicides in the same way to LX3632 as to ordinary carrots.

- When applied pre-emergence of the crop and outside of periods of extreme heat, the effects of high use rates of either of these herbicides tend to be seen as a reduced canopy volume more than as seedling losses leading to poor plant establishment.

- Losses incurred when plantings are made in extreme heat may be compounded by high rates of linuron and prometryn.

- Post-emergent tolerance of LX3632 appears similar to conventional orange carrots. Care needs to be exercised with LX3632 where a staggered germination may result in a wide range of crop growth stages, as seedlings with less than 4 true leaves may be susceptible to damage.

- These herbicides provide carrot growers with more reliable and selective pre and post-emergent control of a wide range of weeds, than is typically available in many other vegetable crops.

Any advice provided in this report is intended as a source of information only. Always read the label before using any of the products mentioned. The Authors of this report do not guarantee that this report is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this report.

Water Management for Black Carrot Production

- Black carrots require ready access to moisture throughout the cropping cycle, particularly during establishment and early development.

- Black carrots require more moisture than standard orange types to maximise yield. Black carrots show reduced **relative** yields and average carrot weights compared with Red Hot as readily available soil moisture in the critical first 4-6 weeks after planting declines.

- Never allow the seed germination zone to dry out after planting until seedlings are well established and clearly able to access moisture at all times. Under hot establishment conditions, increased watering frequency will greatly improve establishment, yield and quality for the same daily quantity of water applied (eg. 3 applications of 3 mm will result in a superior crop to a single application of 9 mm per day). This is a serious limitation to black carrot production under centre pivot irrigation.

- Inadequate moisture during establishment seems to be the main cause of excessive forking in black carrots. The effect may be indirect (eg. Inadequate cooling of soil physically burn roots during early development). Further work would be required to establish this.

- Forking is a more severe problem in black carrots than conventional orange varieties like Red Hot or Apache.

- Irrigation cannot be effectively managed to reduce black carrot canopy vigour while still maintaining high yields.

Technology Transfer

The main findings and the Agronomic Guide will be key platforms for technology extension as soon as this report can be released.

Appendix 1 Miscellaneous Studies & Data

BC0601 – Pre-project commercial LX3632 Crop, Nangiloc, Victoria

This was an early commercial crop grown in the Nangiloc area of northern Victoria for SDS Beverages. The main record was photographs. It was mainly used as a reference for bolting data based on approximate planting date of 11 Mar 2006. Plant stands was quite variable. Anthocyanin development in the small sample shown was good. Bolting was below about 0.1% and harvested some time after 7 Sep 2006 (181+ days).

Photo A1.1. *BC0601 - Early crop of LX3632 at Nangiloc, Vic shortly before harvest, 7 Sep 2006*

Photo A1.2. *BC0601 – Anthocyanin development in carrots from an early crop of LX3632 at Nangiloc, Vic shortly before harvest, 7 Sep 2006*

BC0700 – Pre-project commercial LX3632 Crop, Mersey Lee, Tasmania

This was one of the two last commercial crops to be processed by SDS Beverages in 2007. It was planted 14 Nov 2006 and harvested around 22-25 Mar 2007 (128-130 days after planting).

From data collected on 21 Mar 2007, the following was determined:

Yield: LX3632 49t/ha; Mojo (orange standard) 13 t/ha
Average Carrot Weight: LX3632 108g; Mojo (orange standard) 190g
Average Plant Spacing: LX3632 80mm; 50mm

Carrots were sown in paired (double) rows at 55 cm intervals between the centre of one pair of rows and the next.

Severe (100%) infection of carrots and tops by Sclerotinia (Photo A1.3). The crowns of many carrots were also damaged by the disease.

Extensive bolting (approximately 30-40%) had also occurred, although it was not easy to determine this accurately without a canopy present. This in conjunction with the Sclerotinia damage to foliage led to the grower having slashed all the tops with a view to using a potato harvester to dig.

Colour development was highly variable with roughly an even split between good and poor anthocyanin development (Photo A1.7).

A high degree of size and shape variability is shown in Table A1.1 and Photos A1.4. & A1.6.

Photo A1.3. *BC0700 – Sclerotinia affecting the crowns of LX3632 carrots.*

Photo A1.4. *BC0700 – Harvest sample of LX3632 from 1.0 m of double row*

Photo A1.5. *BC0700 – Harvest sample of Mojo from 1.0 m of double row*

Photo A1.6. *BC0700 – Variability and secondary root development in LX3632 c/w Mojo*

Table A1.1 *BC0700 – Variability in a 50 carrot sample from an early crop of LX3632 at Mersey Lee, Tasmania, shortly before harvest, 21 Mar 2007.*

	50 Carrot Sample	
	Root length (mm)	**Shoulder diameter (mm)**
	300	48
	220	46
	180	40
	150	30
	220	40
	200	40
	170	35
	200	40
	240	45
	200	40
	230	35
	200	40
	200	38
	240	40
	240	70
	200	35
	200	50
	180	32
	190	40
	200	32
	200	55
	180	45
	200	20
	180	40
	210	23
	220	60
	220	45
	200	40
	180	35
	190	45
	210	50
	210	20
	200	38
	220	42
	200	50
	200	45
	200	35
	260	35
	200	35
	180	45
	200	30
	100	30
	190	33
	200	40
	150	35
	140	40
	220	50
	180	50
	300	30
	180	32
Average	201.6	39.8
SE	4.7	1.3
Largest	300	70
Smallest	100	20

Photo A1.7. *BC0700 – Variability in Anthocyanin expression in a 50 carrot LX3632 sample*

BC0701 – Early project commercial LX3632 Crop, Robinvale, Victoria 2007

This was the later of the two last commercial crops to be processed by SDS Beverages in 2007. A series of planting occurred on 09, 16, 19 & 22 Feb 2007. On 03 Apr 2007 a field visit was made:

Table A1.2. *BC0701 – LX3632 & Red Hot Plant Establishment Data 40-53 days after planting, Robinvale, Victoria 2007*

	LX3632 Planting 1 **(Planted 9 Feb 2007)**	**LX3632 Planting 2** **(Planted 16 Feb 2007)**	**LX3632 Planting 3** **(Planted 19 Feb 2007)**	**LX3632 Planting 4** **(Planted 22 Feb 2007)**	**Red Hot** **(Planted 9 Feb 2007)**
Plants/m Bed (4.0 linear m of row)	20.5	19.1	21.8	36.4	74.0
Av. Plant Sapcing (mm)	195	209	183	110	54
Fully Expanded Leaves/Plant	7.4	6.9	6.4	5.0	5.2

The extremely wide average spacings for LX3632 in Table A1.2. are mainly a reflection of a very low seeding rate. Patchy establishment (Photo A1.8.) in some locations was likely a reflection of shallow sowing combined with hot weather during establishment (Section 9.2).

A sample was also taken for pathology after discovering significant seedling damage mainly associated with extreme weakness from "pinching" at the base of the stem. The report showed *Fusarium* was consistently present, *Sclerotium rolsii* was frequently present and *Rhizoctonia* was occasionally present. *Sclerotium rolfsi* is the cause Southern blight in other countries, but is not known to be a significant problem locally. In addition, the symptoms of this are quite different to those already described. *Fusarium* and *Rhizoctonia* were not thought likely to be the primary cause of the problem and were more likely secondary infections.

Photo A1.8. *BC0701 – Patchy establishment seen in some areas.*

NB: Photographs (9.2.5 & 9.2.6) of the "pinching" symptoms around the crown of the plant can be found in Section 9.2 (Case Study 4).

Pre-Harvest Assessments made 17 Jul 2007:

Table A1.3. *BC0701 – LX3632 & Red Hot Pre-harvest Data, 145-158 days after planting, Robinvale, Victoria 2007*

	LX3632 Planting 1 (Planted 9 Feb 2007)	**LX3632 Planting 4 (Planted 16 Feb 2007)**
Plants/m Bed (4.0 linear m of row)	26.3	44.0
Av. Carrot Weight (g)	187	78
Av. Plant Sapcing (mm)	152	91
Estimated TOTAL Yield (t/ha)	30.7	21.5
Actual Harvested Yield (t/ha)	22.239 average from all 4 plantings	
Av. Brix (°Br)	11.1	10.2

Anthocyanin development was visually assessed and was rated as good in about 75% of carrots in both plantings (Photos A1.14. & A1.15.)

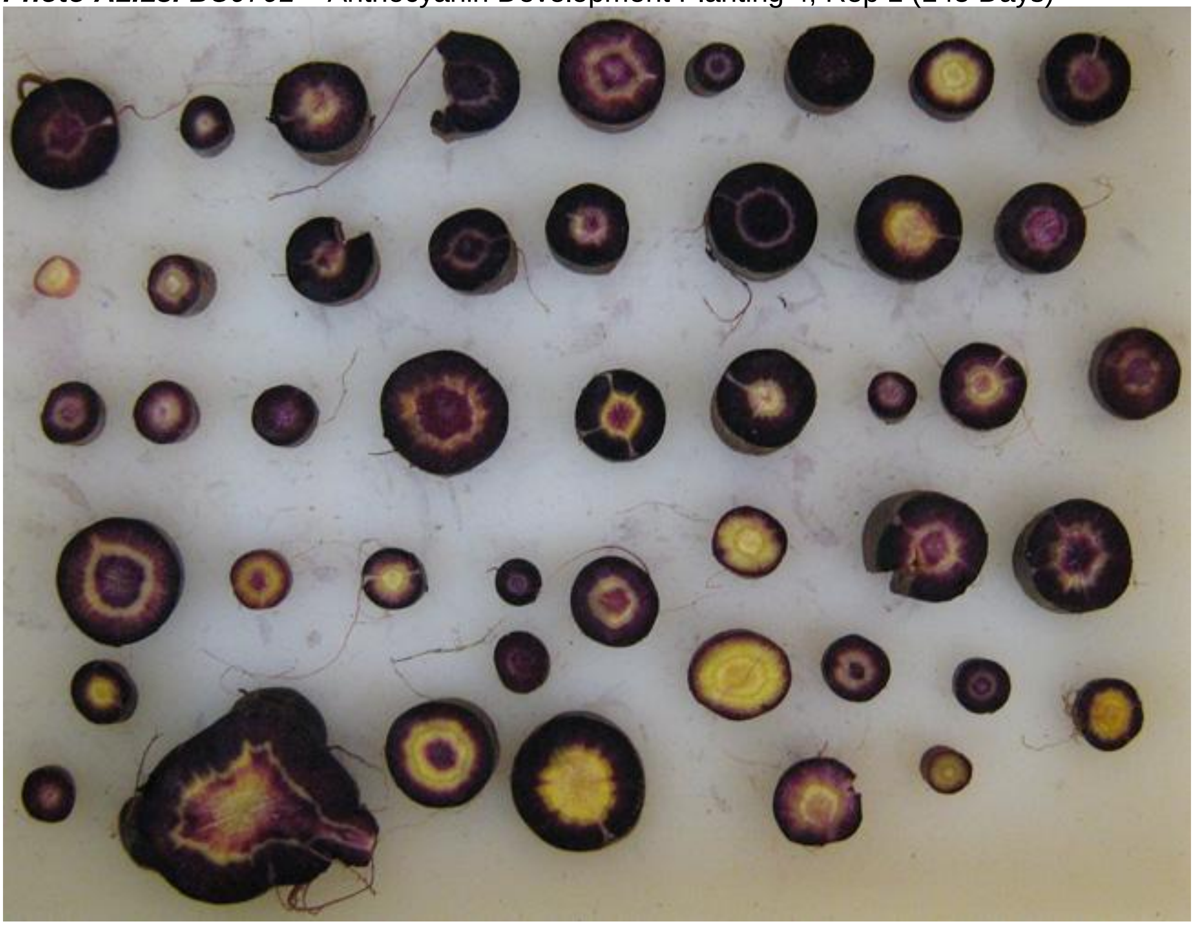
Photo A1.9 *BC0701 – Red Hot (left) & LX3632 Planting 4 (right) showing very little bolting prior to harvest (<0.1%)*

Photo A1.10 *BC0701 – LX3632 Planting 4 and adjacent Red Hot Crop showing relative size of carrots prior to harvest. Note that Red Hot was growing at about 2-3 times the plant density of LX3632*

Photo A1.11 *BC0701 – LX3632 Planting 1 showing fibrous root production and forking*

Photo A1.12. *BC0701* – Anthocyanin Development Planting 1, Rep 1 (158 Days)

Photo A1.13. *BC0701* – Anthocyanin Development Planting 4, Rep 1 (145 Days)



Appendix 2 Variety Photographs

Photo A2.1 *- BC0706, Clyde, Vic, 2007-08. Washed harvest sample LX3632 (Standard).*

Photo A2.2 *- BC0706, Clyde, Vic, 2007-08. Washed harvest sample LX254-7.*

Photo A2.3 *- BC0706, Clyde, Vic, 2007-08. Washed harvest sample LX255-7.*

Photo A2.4 *- BC0706, Clyde, Vic, 2007-08. Root Cross sections - LX3632*

Photo A2.5 *- BC0706, Clyde, Vic, 2007-08. Root Cross sections – LX254-7*

Photo A2.6 *- BC0706, Clyde, Vic, 2007-08. Root Cross sections – LX255-7*

Photo A2.7 *- BC0706, Clyde, Vic, 2007-08. R1 Harvest Sample LX3626*

Photo A2.8 *- BC0706, Clyde, Vic, 2007-08. R2 Harvest Sample LX3626*

Photo A2.9 *- BC0706, Clyde, Vic, 2007-08. R3 Harvest Sample LX3626*

Photo A2.10 *- BC0706, Clyde, Vic, 2007-08. R1 Harvest Sample LX254-7*

Photo A2.11 *- BC0706, Clyde, Vic, 2007-08. R2 Harvest Sample LX254-7*

Photo A2.12 *- BC0706, Clyde, Vic, 2007-08. R3 Harvest Sample LX254-7*

Photo A2.13 *- BC0706, Clyde, Vic, 2007-08. R1 Harvest Sample LX255-7*

Photo A2.14 *- BC0706, Clyde, Vic, 2007-08. R2 Harvest Sample LX255-7*

Photo A2.15 *- BC0706, Clyde, Vic, 2007-08. R3 Harvest Sample LX255-7*

Photo A2.16 *- BC0706, Clyde, Vic, 2007-08. R1 Harvest Sample LX256-7*

Photo A2.17 *- BC0706, Clyde, Vic, 2007-08. R2 Harvest Sample LX256-7*

Photo A2.18 *- BC0706, Clyde, Vic, 2007-08. R3 Harvest Sample LX256-7*

Photo A2.19 *- BC0706, Clyde, Vic, 2007-08. R1 Harvest Sample Red Hot*

Photo A2.19 *- BC0706, Clyde, Vic, 2007-08. R2 Harvest Sample Red Hot*

Photo A2.20 *- BC0706, Clyde, Vic, 2007-08. R3 Harvest Sample Red Hot*

Photo A2.21 *- BC0706, Clyde, Vic, 2007-08. Close up of better examples of LX254-7*

Photo A2.21 *- BC0706, Clyde, Vic, 2007-08. Close up of better examples of LX255-7*

Appendix 3 Weather Data & Thermal Time Calculations

BC0601 – Nangiloc, Vic

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
4/03/2006	17.1	36.9	27.0	0.0	0.0	0.0	0.0	0.0
5/03/2006	17.8	36.7	27.3	0.0	0.0	0.0	0.0	0.0
6/03/2006	16.9	29.2	23.1	0.0	0.0	0.0	0.0	0.0
7/03/2006	11.9	26.1	19.0	0.0	0.0	0.0	0.0	0.0
8/03/2006	11.1	29.5	20.3	0.0	0.0	0.0	0.0	0.0
9/03/2006	15.8	35.2	25.5	0.0	0.0	0.0	0.0	0.0
10/03/2006	14.3	34.5	24.4	0.0	0.0	0.0	0.0	0.0
11/03/2006	14.2	36.0	25.1	0.0	0.0	0.0	0.0	0.0
12/03/2006	18.8	41.4	30.1	0.0	0.0	0.0	0.0	0.0
13/03/2006	21.5	26.3	23.9	0.0	0.0	0.0	0.0	0.0
14/03/2006	10.0	25.4	17.7	0.0	0.0	0.0	0.0	0.0
15/03/2006	13.5	20.4	16.9	0.0	0.0	0.0	0.0	0.0
16/03/2006	11.8	23.6	17.7	0.0	0.0	0.0	0.0	0.0
17/03/2006	9.8	24.5	17.2	0.0	0.0	0.0	0.0	0.0
18/03/2006	10.5	27.1	18.8	0.0	0.0	0.0	0.0	0.0
19/03/2006	11.8	28.1	20.0	0.0	0.0	0.0	0.0	0.0
20/03/2006	13.2	27.2	20.2	0.0	0.0	0.0	0.0	0.0
21/03/2006	14.0	31.9	22.9	0.0	0.0	0.0	0.0	0.0
22/03/2006	16.4	32.8	24.6	0.0	0.0	0.0	0.0	0.0
23/03/2006	15.6	31.6	23.6	0.0	0.0	0.0	0.0	0.0
24/03/2006	15.3	33.0	24.2	0.0	0.0	0.0	0.0	0.0
25/03/2006	17.5	32.7	25.1	0.0	0.0	0.0	0.0	0.0
26/03/2006	16.6	33.3	24.9	0.0	0.0	0.0	0.0	0.0
27/03/2006	19.9	21.4	20.6	0.0	0.0	0.0	0.0	0.0
28/03/2006	15.8	26.6	21.2	0.0	0.0	0.0	0.0	0.0
29/03/2006	14.2	29.9	22.0	0.0	0.0	0.0	0.0	0.0
30/03/2006	15.4	27.3	21.3	0.0	0.0	0.0	0.0	0.0
31/03/2006	9.9	23.1	16.5	0.0	0.0	0.0	0.0	0.0
1/04/2006	11.3	19.7	15.5	15.5	9.0	-0.6	0.4	0.4
2/04/2006	5.9	19.7	12.8	12.8	6.3	1.5	2.5	2.9
3/04/2006	7.7	23.4	15.5	15.5	9.0	-0.6	0.4	3.3
4/04/2006	15.4	24.2	19.8	0.0	0.0	0.0	0.0	3.3
5/04/2006	10.3	22.9	16.6	0.0	0.0	0.0	0.0	3.3
6/04/2006	7.5	19.0	13.3	13.3	6.8	1.2	2.2	5.4
7/04/2006	9.4	21.7	15.6	15.6	9.1	-0.6	0.4	5.8
8/04/2006	5.9	19.6	12.8	12.8	6.3	1.6	2.6	8.4
9/04/2006	3.7	21.0	12.4	12.4	5.9	1.9	2.9	11.2
10/04/2006	5.5	23.8	14.6	14.6	8.1	0.1	1.1	12.3
11/04/2006	8.6	30.4	19.5	0.0	0.0	0.0	0.0	12.3
12/04/2006	10.5	23.8	17.1	0.0	0.0	0.0	0.0	12.3
13/04/2006	13.6	24.6	19.1	0.0	0.0	0.0	0.0	12.3
14/04/2006	16.0	21.5	18.8	0.0	0.0	0.0	0.0	12.3
15/04/2006	6.6	18.9	12.7	12.7	6.2	1.6	2.6	14.9
16/04/2006	2.9	19.2	11.1	11.1	4.6	2.9	3.9	18.8
17/04/2006	4.0	24.0	14.0	14.0	7.5	0.6	1.6	20.4
18/04/2006	10.7	20.1	15.4	15.4	8.9	-0.5	0.5	20.8
19/04/2006	7.7	24.1	15.9	15.9	9.4	-0.9	0.1	20.9
20/04/2006	8.4	19.5	13.9	13.9	7.4	0.6	1.6	22.5
21/04/2006	9.6	17.7	13.7	13.7	7.2	0.9	1.9	24.4
22/04/2006	3.7	16.7	10.2	10.2	3.7	3.6	4.6	29.0
23/04/2006	2.5	17.3	9.9	9.9	3.4	3.8	4.8	33.8
24/04/2006	3.9	19.3	11.6	11.6	5.1	2.5	3.5	37.3
25/04/2006	3.8	18.9	11.3	11.3	4.8	2.7	3.7	40.9
26/04/2006	3.2	25.0	14.1	14.1	7.6	0.5	1.5	42.4
27/04/2006	8.8	26.5	17.7	0.0	0.0	0.0	0.0	42.4
28/04/2006	12.3	16.3	14.3	14.3	7.8	0.3	1.3	43.8

BC0700 – Mersey-Lee (Devonport), Tas

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
14/11/2006	3.0	11.9	7.4	7.4	0.9	5.8	5.8	5.8
15/11/2006	1.2	11.4	6.3	6.3	0.0	0.0	0.0	5.8
16/11/2006	2.8	16.9	9.8	9.8	3.3	3.9	3.9	9.6
17/11/2006	4.1	19.1	11.6	11.6	5.1	2.5	2.5	12.1
18/11/2006	7.7	18.9	13.3	13.3	6.8	1.1	1.1	13.2
19/11/2006	10.5	20.3	15.4	15.4	8.9	-0.5	0.5	13.7
20/11/2006	10.5	20.8	15.6	15.6	9.1	-0.7	0.3	14.0
21/11/2006	8.3	25.9	17.1	0.0	0.0	0.0	0.0	14.0
22/11/2006	10.7	17.1	13.9	13.9	7.4	0.7	0.7	14.6
23/11/2006	11.2	16.7	14.0	14.0	7.5	0.6	0.6	15.2
24/11/2006	4.9	23.1	14.0	14.0	7.5	0.6	0.6	15.8
25/11/2006	11.1	20.8	15.9	15.9	9.4	-1.0	0.0	15.9
26/11/2006	4.2	18.8	11.5	11.5	5.0	2.6	2.6	18.4
27/11/2006	5.0	22.7	13.9	13.9	7.4	0.7	0.7	19.1
28/11/2006	7.7	25.2	16.5	0.0	0.0	0.0	0.0	19.1
29/11/2006	7.1	18.8	12.9	12.9	6.4	1.4	1.4	20.5
30/11/2006	4.8	17.4	11.1	11.1	4.6	2.9	2.9	23.4
1/12/2006	9.2	21.1	15.2	15.2	8.7	-0.3	0.7	24.1
2/12/2006	5.9	14.6	10.3	10.3	3.8	3.5	3.5	27.6
3/12/2006	6.5	18.4	12.4	12.4	5.9	1.8	1.8	29.4
4/12/2006	4.5	19.2	11.9	11.9	5.4	2.3	2.3	31.7
5/12/2006	7.4	23.6	15.5	15.5	9.0	-0.6	0.4	32.1
6/12/2006	11.9	18.6	15.3	15.3	8.8	-0.4	0.6	32.7
7/12/2006	5.3	19.0	12.2	12.2	5.7	2.0	2.0	34.7
8/12/2006	5.7	21.7	13.7	13.7	7.2	0.8	0.8	35.5
9/12/2006	6.5	22.1	14.3	14.3	7.8	0.3	0.3	35.9
10/12/2006	9.1	30.0	19.6	0.0	0.0	0.0	0.0	35.9
11/12/2006	14.9	16.5	15.7	15.7	9.2	-0.8	0.2	36.1
12/12/2006	3.2	18.4	10.8	10.8	4.3	3.1	3.1	39.2
13/12/2006	6.1	18.9	12.5	12.5	6.0	1.8	1.8	41.0
14/12/2006	9.6	21.7	15.7	15.7	9.2	-0.7	0.3	41.2
15/12/2006	3.9	18.9	11.4	11.4	4.9	2.6	2.6	43.9
16/12/2006	6.9	19.5	13.2	13.2	6.7	1.2	1.2	45.1
17/12/2006	6.5	21.0	13.8	13.8	7.3	0.8	0.8	45.9
18/12/2006	8.8	22.1	15.5	15.5	9.0	-0.6	0.4	46.3
19/12/2006	3.9	20.3	12.1	12.1	5.6	2.1	2.1	48.4
20/12/2006	9.3	19.3	14.3	14.3	7.8	0.3	0.3	48.7
21/12/2006	7.6	21.8	14.7	14.7	8.2	0.0	0.0	48.7
22/12/2006	14.5	21.8	18.1	0.0	0.0	0.0	0.0	48.7
23/12/2006	11.3	21.8	16.5	0.0	0.0	0.0	0.0	48.7
24/12/2006	9.8	17.9	13.8	13.8	7.3	0.7	0.7	49.4
25/12/2006	6.0	14.8	10.4	10.4	3.9	3.4	3.4	52.9
26/12/2006	6.3	20.0	13.2	13.2	6.7	1.2	1.2	54.1
27/12/2006	7.2	22.2	14.7	14.7	8.2	0.0	0.0	54.1
28/12/2006	8.5	21.3	14.9	14.9	8.4	-0.1	0.9	55.0
29/12/2006	9.7	19.4	14.5	14.5	8.0	0.1	0.1	55.1
30/12/2006	11.0	19.2	15.1	15.1	8.6	-0.3	0.7	55.9
31/12/2006	11.6	17.7	14.7	14.7	8.2	0.1	0.1	55.9
1/01/2007	13.1	20.1	16.6	0.0	0.0	0.0	0.0	55.9
2/01/2007	11.4	22.8	17.1	0.0	0.0	0.0	0.0	55.9
3/01/2007	13.8	23.0	18.4	0.0	0.0	0.0	0.0	55.9
4/01/2007	11.6	24.5	18.1	0.0	0.0	0.0	0.0	55.9
5/01/2007	13.1	26.5	19.8	0.0	0.0	0.0	0.0	55.9
6/01/2007	13.3	22.9	18.1	0.0	0.0	0.0	0.0	55.9
7/01/2007	14.2	21.3	17.7	0.0	0.0	0.0	0.0	55.9
8/01/2007	8.3	21.1	14.7	14.7	8.2	0.0	0.0	55.9

BC0701 Planting 1 – Robinvale, Vic

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
9/02/2007	12.9	32.0	22.4	0.0	0.0	0.0	0.0	0.0
10/02/2007	14.2	28.1	21.1	0.0	0.0	0.0	0.0	0.0
11/02/2007	15.4	29.2	22.3	0.0	0.0	0.0	0.0	0.0
12/02/2007	18.3	33.3	25.8	0.0	0.0	0.0	0.0	0.0
13/02/2007	20.8	35.0	27.9	0.0	0.0	0.0	0.0	0.0
14/02/2007	20.4	36.7	28.6	0.0	0.0	0.0	0.0	0.0
15/02/2007	21.3	36.3	28.8	0.0	0.0	0.0	0.0	0.0
16/02/2007	19.5	37.0	28.3	0.0	0.0	0.0	0.0	0.0
17/02/2007	22.0	37.0	29.5	0.0	0.0	0.0	0.0	0.0
18/02/2007	23.1	38.0	30.6	0.0	0.0	0.0	0.0	0.0
19/02/2007	23.3	38.1	30.7	0.0	0.0	0.0	0.0	0.0
20/02/2007	21.4	38.3	29.8	0.0	0.0	0.0	0.0	0.0
21/02/2007	21.1	37.2	29.2	0.0	0.0	0.0	0.0	0.0
22/02/2007	19.3	36.3	27.8	0.0	0.0	0.0	0.0	0.0
23/02/2007	18.8	38.6	28.7	0.0	0.0	0.0	0.0	0.0
24/02/2007	19.3	31.5	25.4	0.0	0.0	0.0	0.0	0.0
25/02/2007	16.3	29.6	23.0	0.0	0.0	0.0	0.0	0.0
26/02/2007	15.1	32.5	23.8	0.0	0.0	0.0	0.0	0.0
27/02/2007	17.4	30.2	23.8	0.0	0.0	0.0	0.0	0.0
28/02/2007	15.7	33.0	24.3	0.0	0.0	0.0	0.0	0.0
1/03/2007	18.7	33.1	25.9	0.0	0.0	0.0	0.0	0.0
2/03/2007	17.8	35.8	26.8	0.0	0.0	0.0	0.0	0.0
3/03/2007	20.5	37.6	29.0	0.0	0.0	0.0	0.0	0.0
4/03/2007	15.7	28.3	22.0	0.0	0.0	0.0	0.0	0.0
5/03/2007	15.0	26.5	20.8	0.0	0.0	0.0	0.0	0.0
6/03/2007	11.9	29.1	20.5	0.0	0.0	0.0	0.0	0.0
7/03/2007	14.2	33.0	23.6	0.0	0.0	0.0	0.0	0.0
8/03/2007	14.4	28.8	21.6	0.0	0.0	0.0	0.0	0.0
9/03/2007	11.0	28.6	19.8	0.0	0.0	0.0	0.0	0.0
10/03/2007	10.6	34.0	22.3	0.0	0.0	0.0	0.0	0.0
11/03/2007	15.3	29.0	22.1	0.0	0.0	0.0	0.0	0.0
12/03/2007	12.8	26.9	19.9	0.0	0.0	0.0	0.0	0.0
13/03/2007	11.5	30.9	21.2	0.0	0.0	0.0	0.0	0.0
14/03/2007	13.9	33.8	23.8	0.0	0.0	0.0	0.0	0.0
15/03/2007	18.4	37.1	27.8	0.0	0.0	0.0	0.0	0.0
16/03/2007	23.1	32.1	27.6	0.0	0.0	0.0	0.0	0.0
17/03/2007	15.7	26.9	21.3	0.0	0.0	0.0	0.0	0.0
18/03/2007	11.3	26.3	18.8	0.0	0.0	0.0	0.0	0.0
19/03/2007	13.8	18.9	16.3	0.0	0.0	0.0	0.0	0.0
20/03/2007	14.5	25.3	19.9	0.0	0.0	0.0	0.0	0.0
21/03/2007	16.8	29.9	23.3	0.0	0.0	0.0	0.0	0.0
22/03/2007	18.9	36.8	27.8	0.0	0.0	0.0	0.0	0.0
23/03/2007	21.6	39.0	30.3	0.0	0.0	0.0	0.0	0.0
24/03/2007	15.4	21.9	18.7	0.0	0.0	0.0	0.0	0.0
25/03/2007	9.1	22.6	15.8	15.8	9.3	-0.8	0.2	0.2
26/03/2007	10.5	27.6	19.0	0.0	0.0	0.0	0.0	0.2
27/03/2007	15.3	30.0	22.6	0.0	0.0	0.0	0.0	0.2
28/03/2007	19.2	22.4	20.8	0.0	0.0	0.0	0.0	0.2
29/03/2007	11.8	20.9	16.3	0.0	0.0	0.0	0.0	0.2
30/03/2007	9.4	22.1	15.8	15.8	9.3	-0.8	0.2	0.3
31/03/2007	10.5	23.1	16.8	0.0	0.0	0.0	0.0	0.3
1/04/2007	8.3	26.3	17.3	0.0	0.0	0.0	0.0	0.3
2/04/2007	9.0	29.2	19.1	0.0	0.0	0.0	0.0	0.3
3/04/2007	11.6	26.0	18.8	0.0	0.0	0.0	0.0	0.3
4/04/2007	8.5	25.0	16.8	0.0	0.0	0.0	0.0	0.3
5/04/2007	9.9	23.3	16.6	0.0	0.0	0.0	0.0	0.3

BC0701 Planting 4 – Robinvale, Vic

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
22/02/2007	19.3	36.3	27.8	0.0	0.0	0.0	0.0	0.0
23/02/2007	18.8	38.6	28.7	0.0	0.0	0.0	0.0	0.0
24/02/2007	19.3	31.5	25.4	0.0	0.0	0.0	0.0	0.0
25/02/2007	16.3	29.6	23.0	0.0	0.0	0.0	0.0	0.0
26/02/2007	15.1	32.5	23.8	0.0	0.0	0.0	0.0	0.0
27/02/2007	17.4	30.2	23.8	0.0	0.0	0.0	0.0	0.0
28/02/2007	15.7	33.0	24.3	0.0	0.0	0.0	0.0	0.0
1/03/2007	18.7	33.1	25.9	0.0	0.0	0.0	0.0	0.0
2/03/2007	17.8	35.8	26.8	0.0	0.0	0.0	0.0	0.0
3/03/2007	20.5	37.6	29.0	0.0	0.0	0.0	0.0	0.0
4/03/2007	15.7	28.3	22.0	0.0	0.0	0.0	0.0	0.0
5/03/2007	15.0	26.5	20.8	0.0	0.0	0.0	0.0	0.0
6/03/2007	11.9	29.1	20.5	0.0	0.0	0.0	0.0	0.0
7/03/2007	14.2	33.0	23.6	0.0	0.0	0.0	0.0	0.0
8/03/2007	14.4	28.8	21.6	0.0	0.0	0.0	0.0	0.0
9/03/2007	11.0	28.6	19.8	0.0	0.0	0.0	0.0	0.0
10/03/2007	10.6	34.0	22.3	0.0	0.0	0.0	0.0	0.0
11/03/2007	15.3	29.0	22.1	0.0	0.0	0.0	0.0	0.0
12/03/2007	12.8	26.9	19.9	0.0	0.0	0.0	0.0	0.0
13/03/2007	11.5	30.9	21.2	0.0	0.0	0.0	0.0	0.0
14/03/2007	13.9	33.8	23.8	0.0	0.0	0.0	0.0	0.0
15/03/2007	18.4	37.1	27.8	0.0	0.0	0.0	0.0	0.0
16/03/2007	23.1	32.1	27.6	0.0	0.0	0.0	0.0	0.0
17/03/2007	15.7	26.9	21.3	0.0	0.0	0.0	0.0	0.0
18/03/2007	11.3	26.3	18.8	0.0	0.0	0.0	0.0	0.0
19/03/2007	13.8	18.9	16.3	0.0	0.0	0.0	0.0	0.0
20/03/2007	14.5	25.3	19.9	0.0	0.0	0.0	0.0	0.0
21/03/2007	16.8	29.9	23.3	0.0	0.0	0.0	0.0	0.0
22/03/2007	18.9	36.8	27.8	0.0	0.0	0.0	0.0	0.0
23/03/2007	21.6	39.0	30.3	0.0	0.0	0.0	0.0	0.0
24/03/2007	15.4	21.9	18.7	0.0	0.0	0.0	0.0	0.0
25/03/2007	9.1	22.6	15.8	15.8	9.3	-0.8	0.2	0.2
26/03/2007	10.5	27.6	19.0	0.0	0.0	0.0	0.0	0.2
27/03/2007	15.3	30.0	22.6	0.0	0.0	0.0	0.0	0.2
28/03/2007	19.2	22.4	20.8	0.0	0.0	0.0	0.0	0.2
29/03/2007	11.8	20.9	16.3	0.0	0.0	0.0	0.0	0.2
30/03/2007	9.4	22.1	15.8	15.8	9.3	-0.8	0.2	0.3
31/03/2007	10.5	23.1	16.8	0.0	0.0	0.0	0.0	0.3
1/04/2007	8.3	26.3	17.3	0.0	0.0	0.0	0.0	0.3
2/04/2007	9.0	29.2	19.1	0.0	0.0	0.0	0.0	0.3
3/04/2007	11.6	26.0	18.8	0.0	0.0	0.0	0.0	0.3
4/04/2007	8.5	25.0	16.8	0.0	0.0	0.0	0.0	0.3
5/04/2007	9.9	23.3	16.6	0.0	0.0	0.0	0.0	0.3
6/04/2007	8.3	22.8	15.5	15.5	9.0	-0.6	0.4	0.7
7/04/2007	9.2	26.1	17.6	0.0	0.0	0.0	0.0	0.7
8/04/2007	10.9	27.6	19.2	0.0	0.0	0.0	0.0	0.7
9/04/2007	12.3	28.9	20.6	0.0	0.0	0.0	0.0	0.7
10/04/2007	12.8	29.9	21.3	0.0	0.0	0.0	0.0	0.7
11/04/2007	11.9	30.6	21.3	0.0	0.0	0.0	0.0	0.7
12/04/2007	13.0	30.6	21.8	0.0	0.0	0.0	0.0	0.7
13/04/2007	12.3	30.9	21.6	0.0	0.0	0.0	0.0	0.7
14/04/2007	12.4	31.7	22.1	0.0	0.0	0.0	0.0	0.7
15/04/2007	12.1	23.8	17.9	0.0	0.0	0.0	0.0	0.7
16/04/2007	8.9	24.6	16.8	0.0	0.0	0.0	0.0	0.7
17/04/2007	11.0	28.9	20.0	0.0	0.0	0.0	0.0	0.7
18/04/2007	9.9	23.5	16.7	0.0	0.0	0.0	0.0	0.7

BC0702 Planting 1 – Bowen, Qld

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
2/05/2007	20.2	29.3	24.8	0.0	0.0	0.0	0.0	0.0
3/05/2007	17.8	29.2	23.5	0.0	0.0	0.0	0.0	0.0
4/05/2007	17.2	29.3	23.3	0.0	0.0	0.0	0.0	0.0
5/05/2007	16.8	30.1	23.5	0.0	0.0	0.0	0.0	0.0
6/05/2007	21.4	29.7	25.6	0.0	0.0	0.0	0.0	0.0
7/05/2007	21.7	29.3	25.5	0.0	0.0	0.0	0.0	0.0
8/05/2007	22.1	27.2	24.7	0.0	0.0	0.0	0.0	0.0
9/05/2007	22.2	29.0	25.6	0.0	0.0	0.0	0.0	0.0
10/05/2007	22.3	26.3	24.3	0.0	0.0	0.0	0.0	0.0
11/05/2007	20.9	28.4	24.7	0.0	0.0	0.0	0.0	0.0
12/05/2007	21.1	28.0	24.6	0.0	0.0	0.0	0.0	0.0
13/05/2007	21.6	28.4	25.0	0.0	0.0	0.0	0.0	0.0
14/05/2007	21.3	28.8	25.1	0.0	0.0	0.0	0.0	0.0
15/05/2007	18.3	28.9	23.6	0.0	0.0	0.0	0.0	0.0
16/05/2007	20.1	29.3	24.7	0.0	0.0	0.0	0.0	0.0
17/05/2007	19.0	29.1	24.1	0.0	0.0	0.0	0.0	0.0
18/05/2007	20.1	28.9	24.5	0.0	0.0	0.0	0.0	0.0
19/05/2007	19.3	29.1	24.2	0.0	0.0	0.0	0.0	0.0
20/05/2007	19.5	29.7	24.6	0.0	0.0	0.0	0.0	0.0
21/05/2007	20.2	29.6	24.9	0.0	0.0	0.0	0.0	0.0
22/05/2007	21.3	29.4	25.4	0.0	0.0	0.0	0.0	0.0
23/05/2007	22.8	28.9	25.9	0.0	0.0	0.0	0.0	0.0
24/05/2007	22.4	28.3	25.4	0.0	0.0	0.0	0.0	0.0
25/05/2007	21.3	28.6	25.0	0.0	0.0	0.0	0.0	0.0
26/05/2007	21.7	27.9	24.8	0.0	0.0	0.0	0.0	0.0
27/05/2007	21.7	28.2	25.0	0.0	0.0	0.0	0.0	0.0
28/05/2007	21.0	27.8	24.4	0.0	0.0	0.0	0.0	0.0
29/05/2007	21.3	28.6	25.0	0.0	0.0	0.0	0.0	0.0
30/05/2007	20.8	28.7	24.8	0.0	0.0	0.0	0.0	0.0
31/05/2007	21.2	28.4	24.8	0.0	0.0	0.0	0.0	0.0
1/06/2007	22.0	28.1	25.1	0.0	0.0	0.0	0.0	0.0
2/06/2007	21.8	28.2	25.0	0.0	0.0	0.0	0.0	0.0
3/06/2007	22.2	28.8	25.5	0.0	0.0	0.0	0.0	0.0
4/06/2007	22.7	29.1	25.9	0.0	0.0	0.0	0.0	0.0
5/06/2007	22.6	27.9	25.3	0.0	0.0	0.0	0.0	0.0
6/06/2007	18.0	23.6	20.8	0.0	0.0	0.0	0.0	0.0
7/06/2007	16.4	20.8	18.6	0.0	0.0	0.0	0.0	0.0
8/06/2007	10.2	21.2	15.7	15.7	9.2	-0.8	0.2	0.2
9/06/2007	9.2	23.1	16.2	0.0	0.0	0.0	0.0	0.2
10/06/2007	9.8	23.9	16.9	0.0	0.0	0.0	0.0	0.2
11/06/2007	11.6	24.7	18.2	0.0	0.0	0.0	0.0	0.2
12/06/2007	12.2	25.5	18.9	0.0	0.0	0.0	0.0	0.2
13/06/2007	15.0	24.7	19.9	0.0	0.0	0.0	0.0	0.2
14/06/2007	16.4	20.2	18.3	0.0	0.0	0.0	0.0	0.2
15/06/2007	17.4	20.8	19.1	0.0	0.0	0.0	0.0	0.2
16/06/2007	18.2	24.8	21.5	0.0	0.0	0.0	0.0	0.2
17/06/2007	16.3	22.8	19.6	0.0	0.0	0.0	0.0	0.2
18/06/2007	14.8	18.3	16.6	0.0	0.0	0.0	0.0	0.2
19/06/2007	16.9	21.3	19.1	0.0	0.0	0.0	0.0	0.2
20/06/2007	15.6	18.8	17.2	0.0	0.0	0.0	0.0	0.2
21/06/2007	11.8	15.6	13.7	13.7	7.2	0.8	0.8	1.1
22/06/2007	12.8	15.4	14.1	14.1	7.6	0.5	0.5	1.6
23/06/2007	13.3	19.7	16.5	0.0	0.0	0.0	0.0	1.6
24/06/2007	17.1	21.5	19.3	0.0	0.0	0.0	0.0	1.6
25/06/2007	17.8	23.9	20.9	0.0	0.0	0.0	0.0	1.6
26/06/2007	16.9	20.8	18.9	0.0	0.0	0.0	0.0	1.6

BC0702 Planting 2 – Bowen, Qld

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
25/05/2007	21.3	28.6	25.0	0.0	0.0	0.0	0.0	0.0
26/05/2007	21.7	27.9	24.8	0.0	0.0	0.0	0.0	0.0
27/05/2007	21.7	28.2	25.0	0.0	0.0	0.0	0.0	0.0
28/05/2007	21.0	27.8	24.4	0.0	0.0	0.0	0.0	0.0
29/05/2007	21.3	28.6	25.0	0.0	0.0	0.0	0.0	0.0
30/05/2007	20.8	28.7	24.8	0.0	0.0	0.0	0.0	0.0
31/05/2007	21.2	28.4	24.8	0.0	0.0	0.0	0.0	0.0
1/06/2007	22.0	28.1	25.1	0.0	0.0	0.0	0.0	0.0
2/06/2007	21.8	28.2	25.0	0.0	0.0	0.0	0.0	0.0
3/06/2007	22.2	28.8	25.5	0.0	0.0	0.0	0.0	0.0
4/06/2007	22.7	29.1	25.9	0.0	0.0	0.0	0.0	0.0
5/06/2007	22.6	27.9	25.3	0.0	0.0	0.0	0.0	0.0
6/06/2007	18.0	23.6	20.8	0.0	0.0	0.0	0.0	0.0
7/06/2007	16.4	20.8	18.6	0.0	0.0	0.0	0.0	0.0
8/06/2007	10.2	21.2	15.7	15.7	9.2	-0.8	0.2	0.2
9/06/2007	9.2	23.1	16.2	0.0	0.0	0.0	0.0	0.2
10/06/2007	9.8	23.9	16.9	0.0	0.0	0.0	0.0	0.2
11/06/2007	11.6	24.7	18.2	0.0	0.0	0.0	0.0	0.2
12/06/2007	12.2	25.5	18.9	0.0	0.0	0.0	0.0	0.2
13/06/2007	15.0	24.7	19.9	0.0	0.0	0.0	0.0	0.2
14/06/2007	16.4	20.2	18.3	0.0	0.0	0.0	0.0	0.2
15/06/2007	17.4	20.8	19.1	0.0	0.0	0.0	0.0	0.2
16/06/2007	18.2	24.8	21.5	0.0	0.0	0.0	0.0	0.2
17/06/2007	16.3	22.8	19.6	0.0	0.0	0.0	0.0	0.2
18/06/2007	14.8	18.3	16.6	0.0	0.0	0.0	0.0	0.2
19/06/2007	16.9	21.3	19.1	0.0	0.0	0.0	0.0	0.2
20/06/2007	15.6	18.8	17.2	0.0	0.0	0.0	0.0	0.2
21/06/2007	11.8	15.6	13.7	13.7	7.2	0.8	0.8	1.1
22/06/2007	12.8	15.4	14.1	14.1	7.6	0.5	0.5	1.6
23/06/2007	13.3	19.7	16.5	0.0	0.0	0.0	0.0	1.6
24/06/2007	17.1	21.5	19.3	0.0	0.0	0.0	0.0	1.6
25/06/2007	17.8	23.9	20.9	0.0	0.0	0.0	0.0	1.6
26/06/2007	16.9	20.8	18.9	0.0	0.0	0.0	0.0	1.6
27/06/2007	12.6	21.1	16.9	0.0	0.0	0.0	0.0	1.6
28/06/2007	8.0	21.0	14.5	14.5	8.0	0.2	0.2	1.7
29/06/2007	9.6	22.0	15.8	15.8	9.3	-0.8	0.2	1.9
30/06/2007	10.2	24.2	17.2	0.0	0.0	0.0	0.0	1.9
1/07/2007	9.8	24.7	17.3	0.0	0.0	0.0	0.0	1.9
2/07/2007	10.7	25.3	18.0	0.0	0.0	0.0	0.0	1.9
3/07/2007	11.3	24.8	18.1	0.0	0.0	0.0	0.0	1.9
4/07/2007	11.2	24.3	17.8	0.0	0.0	0.0	0.0	1.9
5/07/2007	11.9	28.3	20.1	0.0	0.0	0.0	0.0	1.9
6/07/2007	11.4	24.9	18.2	0.0	0.0	0.0	0.0	1.9
7/07/2007	10.1	23.8	17.0	0.0	0.0	0.0	0.0	1.9
8/07/2007	11.1	24.8	18.0	0.0	0.0	0.0	0.0	1.9
9/07/2007	10.3	22.6	16.5	0.0	0.0	0.0	0.0	1.9
10/07/2007	7.3	21.4	14.4	14.4	7.9	0.3	0.3	2.2
11/07/2007	9.8	24.4	17.1	0.0	0.0	0.0	0.0	2.2
12/07/2007	11.9	23.0	17.5	0.0	0.0	0.0	0.0	2.2
13/07/2007	8.9	22.1	15.5	15.5	9.0	-0.6	0.4	2.6
14/07/2007	7.2	20.8	14.0	14.0	7.5	0.6	0.6	3.2
15/07/2007	6.7	21.8	14.3	14.3	7.8	0.4	0.4	3.6
16/07/2007	8.6	22.9	15.8	15.8	9.3	-0.8	0.2	3.8
17/07/2007	11.5	23.8	17.7	0.0	0.0	0.0	0.0	3.8
18/07/2007	12.5	24.1	18.3	0.0	0.0	0.0	0.0	3.8
19/07/2007	9.8	21.9	15.9	15.9	9.4	-0.9	0.1	3.9

BC0702 Planting 3 – Bowen, Qld

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
17/07/2007	11.5	23.8	17.7	0.0	0.0	0.0	0.0	0.0
18/07/2007	12.5	24.1	18.3	0.0	0.0	0.0	0.0	0.0
19/07/2007	9.8	21.9	15.9	15.9	9.4	-0.9	0.1	0.1
20/07/2007	5.8	20.8	13.3	13.3	6.8	1.1	1.1	1.3
21/07/2007	8.1	22.6	15.4	15.4	8.9	-0.5	0.5	1.8
22/07/2007	11.4	23.6	17.5	0.0	0.0	0.0	0.0	1.8
23/07/2007	17.4	24.2	20.8	0.0	0.0	0.0	0.0	1.8
24/07/2007	17.5	23.3	20.4	0.0	0.0	0.0	0.0	1.8
25/07/2007	18.2	25.7	22.0	0.0	0.0	0.0	0.0	1.8
26/07/2007	18.7	25.4	22.1	0.0	0.0	0.0	0.0	1.8
27/07/2007	17.9	25.9	21.9	0.0	0.0	0.0	0.0	1.8
28/07/2007	14.7	26.2	20.5	0.0	0.0	0.0	0.0	1.8
29/07/2007	12.3	26.8	19.6	0.0	0.0	0.0	0.0	1.8
30/07/2007	12.7	27.1	19.9	0.0	0.0	0.0	0.0	1.8
31/07/2007	10.1	25.6	17.9	0.0	0.0	0.0	0.0	1.8
1/08/2007	12.8	25.3	19.1	0.0	0.0	0.0	0.0	1.8
2/08/2007	13.8	26.2	20.0	0.0	0.0	0.0	0.0	1.8
3/08/2007	14.9	26.6	20.8	0.0	0.0	0.0	0.0	1.8
4/08/2007	14.4	28.8	21.6	0.0	0.0	0.0	0.0	1.8
5/08/2007	19.4	20.4	19.9	0.0	0.0	0.0	0.0	1.8
6/08/2007	11.8	19.6	15.7	15.7	9.2	-0.8	0.2	2.0
7/08/2007	8.0	24.3	16.2	0.0	0.0	0.0	0.0	2.0
8/08/2007	18.2	25.6	21.9	0.0	0.0	0.0	0.0	2.0
9/08/2007	18.2	23.7	21.0	0.0	0.0	0.0	0.0	2.0
10/08/2007	16.0	26.2	21.1	0.0	0.0	0.0	0.0	2.0
11/08/2007	15.8	26.3	21.1	0.0	0.0	0.0	0.0	2.0
12/08/2007	13.9	26.3	20.1	0.0	0.0	0.0	0.0	2.0
13/08/2007	18.2	26.9	22.6	0.0	0.0	0.0	0.0	2.0
14/08/2007	16.8	26.5	21.7	0.0	0.0	0.0	0.0	2.0
15/08/2007	19.5	26.4	23.0	0.0	0.0	0.0	0.0	2.0
16/08/2007	20.6	27.7	24.2	0.0	0.0	0.0	0.0	2.0
17/08/2007	20.1	27.2	23.7	0.0	0.0	0.0	0.0	2.0
18/08/2007	17.4	25.6	21.5	0.0	0.0	0.0	0.0	2.0
19/08/2007	18.4	24.4	21.4	0.0	0.0	0.0	0.0	2.0
20/08/2007	18.2	24.4	21.3	0.0	0.0	0.0	0.0	2.0
21/08/2007	14.9	23.9	19.4	0.0	0.0	0.0	0.0	2.0
22/08/2007	12.3	25.2	18.8	0.0	0.0	0.0	0.0	2.0
23/08/2007	16.0	25.2	20.6	0.0	0.0	0.0	0.0	2.0
24/08/2007	14.6	26.3	20.5	0.0	0.0	0.0	0.0	2.0
25/08/2007	13.9	26.4	20.2	0.0	0.0	0.0	0.0	2.0
26/08/2007	15.3	27.5	21.4	0.0	0.0	0.0	0.0	2.0
27/08/2007	18.6	26.6	22.6	0.0	0.0	0.0	0.0	2.0
28/08/2007	17.9	26.1	22.0	0.0	0.0	0.0	0.0	2.0
29/08/2007	19.2	25.5	22.4	0.0	0.0	0.0	0.0	2.0
30/08/2007	19.2	26.5	22.9	0.0	0.0	0.0	0.0	2.0
31/08/2007	18.5	27.5	23.0	0.0	0.0	0.0	0.0	2.0
1/09/2007	19.4	25.9	22.7	0.0	0.0	0.0	0.0	2.0
2/09/2007	16.6	25.4	21.0	0.0	0.0	0.0	0.0	2.0
3/09/2007	19.1	27.3	23.2	0.0	0.0	0.0	0.0	2.0
4/09/2007	19.9	25.2	22.6	0.0	0.0	0.0	0.0	2.0
5/09/2007	18.9	25.3	22.1	0.0	0.0	0.0	0.0	2.0
6/09/2007	16.8	25.3	21.1	0.0	0.0	0.0	0.0	2.0
7/09/2007	16.4	26.9	21.7	0.0	0.0	0.0	0.0	2.0
8/09/2007	15.4	26.2	20.8	0.0	0.0	0.0	0.0	2.0
9/09/2007	15.4	26.8	21.1	0.0	0.0	0.0	0.0	2.0
10/09/2007	16.2	26.4	21.3	0.0	0.0	0.0	0.0	2.0

BC0703 Planting 1 – Katherine, NT

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
24/05/2007	12.6	32.7	22.7	0.0	0.0	0.0	0.0	0.0
25/05/2007	21.5	33.4	27.5	0.0	0.0	0.0	0.0	0.0
26/05/2007	19.5	34.6	27.0	0.0	0.0	0.0	0.0	0.0
27/05/2007	22.2	34.1	28.1	0.0	0.0	0.0	0.0	0.0
28/05/2007	19.8	34.3	27.0	0.0	0.0	0.0	0.0	0.0
29/05/2007	20.7	34.5	27.6	0.0	0.0	0.0	0.0	0.0
30/05/2007	20.4	33.1	26.7	0.0	0.0	0.0	0.0	0.0
31/05/2007	21.6	31.9	26.8	0.0	0.0	0.0	0.0	0.0
1/06/2007	19.2	31.6	25.4	0.0	0.0	0.0	0.0	0.0
2/06/2007	17.5	31.7	24.6	0.0	0.0	0.0	0.0	0.0
3/06/2007	19.9	29.4	24.6	0.0	0.0	0.0	0.0	0.0
4/06/2007	17.7	30.1	23.9	0.0	0.0	0.0	0.0	0.0
5/06/2007	17.1	31.1	24.1	0.0	0.0	0.0	0.0	0.0
6/06/2007	19.7	33.6	26.6	0.0	0.0	0.0	0.0	0.0
7/06/2007	18.3	29.1	23.7	0.0	0.0	0.0	0.0	0.0
8/06/2007	10.6	25.7	18.2	0.0	0.0	0.0	0.0	0.0
9/06/2007	7.0	24.6	15.8	15.8	9.3	-0.8	0.2	0.2
10/06/2007	6.6	26.6	16.6	0.0	0.0	0.0	0.0	0.2
11/06/2007	7.9	27.9	17.9	0.0	0.0	0.0	0.0	0.2
12/06/2007	10.7	28.2	19.5	0.0	0.0	0.0	0.0	0.2
13/06/2007	11.5	28.4	19.9	0.0	0.0	0.0	0.0	0.2
14/06/2007	12.5	29.0	20.8	0.0	0.0	0.0	0.0	0.2
15/06/2007	15.3	29.7	22.5	0.0	0.0	0.0	0.0	0.2
16/06/2007	18.2	30.0	24.1	0.0	0.0	0.0	0.0	0.2
17/06/2007	20.4	25.2	22.8	0.0	0.0	0.0	0.0	0.2
18/06/2007	18.2	27.0	22.6	0.0	0.0	0.0	0.0	0.2
19/06/2007	19.0	22.3	20.6	0.0	0.0	0.0	0.0	0.2
20/06/2007	14.7	16.5	15.6	15.6	9.1	-0.7	0.3	0.5
21/06/2007	14.2	20.7	17.5	0.0	0.0	0.0	0.0	0.5
22/06/2007	15.5	20.4	17.9	0.0	0.0	0.0	0.0	0.5
23/06/2007	16.0	26.5	21.3	0.0	0.0	0.0	0.0	0.5
24/06/2007	18.1	26.6	22.4	0.0	0.0	0.0	0.0	0.5
25/06/2007	18.2	22.0	20.1	0.0	0.0	0.0	0.0	0.5
26/06/2007	16.0	25.5	20.8	0.0	0.0	0.0	0.0	0.5
27/06/2007	12.5	24.5	18.5	0.0	0.0	0.0	0.0	0.5
28/06/2007	5.7	25.0	15.3	15.3	8.8	-0.5	0.5	1.0
29/06/2007	4.4	25.5	15.0	15.0	8.5	-0.2	0.8	1.8
30/06/2007	4.4	28.1	16.3	0.0	0.0	0.0	0.0	1.8
1/07/2007	6.1	29.4	17.7	0.0	0.0	0.0	0.0	1.8
2/07/2007	6.8	30.9	18.8	0.0	0.0	0.0	0.0	1.8
3/07/2007	9.8	30.7	20.3	0.0	0.0	0.0	0.0	1.8
4/07/2007	10.2	31.2	20.7	0.0	0.0	0.0	0.0	1.8
5/07/2007	10.6	30.9	20.8	0.0	0.0	0.0	0.0	1.8
6/07/2007	10.9	29.0	19.9	0.0	0.0	0.0	0.0	1.8
7/07/2007	7.0	27.9	17.4	0.0	0.0	0.0	0.0	1.8
8/07/2007	8.9	26.6	17.8	0.0	0.0	0.0	0.0	1.8
9/07/2007	10.3	25.2	17.8	0.0	0.0	0.0	0.0	1.8
10/07/2007	5.8	24.7	15.3	15.3	8.8	-0.4	0.6	2.4
11/07/2007	4.4	25.5	15.0	15.0	8.5	-0.2	0.8	3.2
12/07/2007	5.5	26.4	15.9	15.9	9.4	-1.0	0.0	3.3
13/07/2007	6.3	28.5	17.4	0.0	0.0	0.0	0.0	3.3
14/07/2007	9.9	29.0	19.4	0.0	0.0	0.0	0.0	3.3
15/07/2007	12.5	29.1	20.8	0.0	0.0	0.0	0.0	3.3
16/07/2007	13.8	29.7	21.8	0.0	0.0	0.0	0.0	3.3
17/07/2007	12.7	29.7	21.2	0.0	0.0	0.0	0.0	3.3
18/07/2007	12.7	29.2	21.0	0.0	0.0	0.0	0.0	3.3

BC0703 Planting 2 – Katherine, NT

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
14/06/2007	12.5	29.0	20.8	0.0	0.0	0.0	0.0	0.0
15/06/2007	15.3	29.7	22.5	0.0	0.0	0.0	0.0	0.0
16/06/2007	18.2	30.0	24.1	0.0	0.0	0.0	0.0	0.0
17/06/2007	20.4	25.2	22.8	0.0	0.0	0.0	0.0	0.0
18/06/2007	18.2	27.0	22.6	0.0	0.0	0.0	0.0	0.0
19/06/2007	19.0	22.3	20.6	0.0	0.0	0.0	0.0	0.0
20/06/2007	14.7	16.5	15.6	15.6	9.1	-0.7	0.3	0.3
21/06/2007	14.2	20.7	17.5	0.0	0.0	0.0	0.0	0.3
22/06/2007	15.5	20.4	17.9	0.0	0.0	0.0	0.0	0.3
23/06/2007	16.0	26.5	21.3	0.0	0.0	0.0	0.0	0.3
24/06/2007	18.1	26.6	22.4	0.0	0.0	0.0	0.0	0.3
25/06/2007	18.2	22.0	20.1	0.0	0.0	0.0	0.0	0.3
26/06/2007	16.0	25.5	20.8	0.0	0.0	0.0	0.0	0.3
27/06/2007	12.5	24.5	18.5	0.0	0.0	0.0	0.0	0.3
28/06/2007	5.7	25.0	15.3	15.3	8.8	-0.5	0.5	0.8
29/06/2007	4.4	25.5	15.0	15.0	8.5	-0.2	0.8	1.7
30/06/2007	4.4	28.1	16.3	0.0	0.0	0.0	0.0	1.7
1/07/2007	6.1	29.4	17.7	0.0	0.0	0.0	0.0	1.7
2/07/2007	6.8	30.9	18.8	0.0	0.0	0.0	0.0	1.7
3/07/2007	9.8	30.7	20.3	0.0	0.0	0.0	0.0	1.7
4/07/2007	10.2	31.2	20.7	0.0	0.0	0.0	0.0	1.7
5/07/2007	10.6	30.9	20.8	0.0	0.0	0.0	0.0	1.7
6/07/2007	10.9	29.0	19.9	0.0	0.0	0.0	0.0	1.7
7/07/2007	7.0	27.9	17.4	0.0	0.0	0.0	0.0	1.7
8/07/2007	8.9	26.6	17.8	0.0	0.0	0.0	0.0	1.7
9/07/2007	10.3	25.2	17.8	0.0	0.0	0.0	0.0	1.7
10/07/2007	5.8	24.7	15.3	15.3	8.8	-0.4	0.6	2.2
11/07/2007	4.4	25.5	15.0	15.0	8.5	-0.2	0.8	3.1
12/07/2007	5.5	26.4	15.9	15.9	9.4	-1.0	0.0	3.1
13/07/2007	6.3	28.5	17.4	0.0	0.0	0.0	0.0	3.1
14/07/2007	9.9	29.0	19.4	0.0	0.0	0.0	0.0	3.1
15/07/2007	12.5	29.1	20.8	0.0	0.0	0.0	0.0	3.1
16/07/2007	13.8	29.7	21.8	0.0	0.0	0.0	0.0	3.1
17/07/2007	12.7	29.7	21.2	0.0	0.0	0.0	0.0	3.1
18/07/2007	12.7	29.2	21.0	0.0	0.0	0.0	0.0	3.1
19/07/2007	12.6	28.0	20.3	0.0	0.0	0.0	0.0	3.1
20/07/2007	10.2	28.0	19.1	0.0	0.0	0.0	0.0	3.1
21/07/2007	8.1	27.9	18.0	0.0	0.0	0.0	0.0	3.1
22/07/2007	10.5	28.4	19.4	0.0	0.0	0.0	0.0	3.1
23/07/2007	12.8	29.9	21.3	0.0	0.0	0.0	0.0	3.1
24/07/2007	15.5	31.1	23.3	0.0	0.0	0.0	0.0	3.1
25/07/2007	13.8	30.4	22.1	0.0	0.0	0.0	0.0	3.1
26/07/2007	12.6	31.9	22.3	0.0	0.0	0.0	0.0	3.1
27/07/2007	15.5	32.0	23.8	0.0	0.0	0.0	0.0	3.1
28/07/2007	14.8	31.6	23.2	0.0	0.0	0.0	0.0	3.1
29/07/2007	13.9	31.7	22.8	0.0	0.0	0.0	0.0	3.1
30/07/2007	12.5	32.3	22.4	0.0	0.0	0.0	0.0	3.1
31/07/2007	11.8	31.5	21.7	0.0	0.0	0.0	0.0	3.1
1/08/2007	11.6	31.0	21.3	0.0	0.0	0.0	0.0	3.1
2/08/2007	13.6	32.1	22.8	0.0	0.0	0.0	0.0	3.1
3/08/2007	15.0	32.6	23.8	0.0	0.0	0.0	0.0	3.1
4/08/2007	16.2	30.9	23.6	0.0	0.0	0.0	0.0	3.1
5/08/2007	15.9	28.9	22.4	0.0	0.0	0.0	0.0	3.1
6/08/2007	11.6	28.0	19.8	0.0	0.0	0.0	0.0	3.1
7/08/2007	10.2	29.7	20.0	0.0	0.0	0.0	0.0	3.1
8/08/2007	10.8	30.1	20.5	0.0	0.0	0.0	0.0	3.1

BC0704 Planting 1 – Darwin, NT

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
9/05/2007	22.1	34.5	28.3	0.0	0.0	0.0	0.0	0.0
10/05/2007	23.5	32.9	28.2	0.0	0.0	0.0	0.0	0.0
11/05/2007	22.3	33.5	27.9	0.0	0.0	0.0	0.0	0.0
12/05/2007	22.2	32.5	27.4	0.0	0.0	0.0	0.0	0.0
13/05/2007	21.9	31.6	26.8	0.0	0.0	0.0	0.0	0.0
14/05/2007	24.0	32.5	28.3	0.0	0.0	0.0	0.0	0.0
15/05/2007	24.8	32.8	28.8	0.0	0.0	0.0	0.0	0.0
16/05/2007	24.7	32.4	28.6	0.0	0.0	0.0	0.0	0.0
17/05/2007	24.1	33.1	28.6	0.0	0.0	0.0	0.0	0.0
18/05/2007	24.5	32.7	28.6	0.0	0.0	0.0	0.0	0.0
19/05/2007	24.9	33.7	29.3	0.0	0.0	0.0	0.0	0.0
20/05/2007	24.0	33.5	28.8	0.0	0.0	0.0	0.0	0.0
21/05/2007	24.4	33.9	29.2	0.0	0.0	0.0	0.0	0.0
22/05/2007	24.5	33.2	28.9	0.0	0.0	0.0	0.0	0.0
23/05/2007	20.9	32.8	26.8	0.0	0.0	0.0	0.0	0.0
24/05/2007	21.1	32.9	27.0	0.0	0.0	0.0	0.0	0.0
25/05/2007	24.0	33.4	28.7	0.0	0.0	0.0	0.0	0.0
26/05/2007	25.4	33.4	29.4	0.0	0.0	0.0	0.0	0.0
27/05/2007	24.0	33.4	28.7	0.0	0.0	0.0	0.0	0.0
28/05/2007	24.8	33.7	29.3	0.0	0.0	0.0	0.0	0.0
29/05/2007	23.9	33.8	28.8	0.0	0.0	0.0	0.0	0.0
30/05/2007	23.9	33.2	28.6	0.0	0.0	0.0	0.0	0.0
31/05/2007	23.5	33.2	28.4	0.0	0.0	0.0	0.0	0.0
1/06/2007	24.6	32.0	28.3	0.0	0.0	0.0	0.0	0.0
2/06/2007	23.7	32.7	28.2	0.0	0.0	0.0	0.0	0.0
3/06/2007	23.5	33.3	28.4	0.0	0.0	0.0	0.0	0.0
4/06/2007	21.6	32.6	27.1	0.0	0.0	0.0	0.0	0.0
5/06/2007	22.0	33.1	27.5	0.0	0.0	0.0	0.0	0.0
6/06/2007	23.5	33.9	28.7	0.0	0.0	0.0	0.0	0.0
7/06/2007	23.4	32.8	28.1	0.0	0.0	0.0	0.0	0.0
8/06/2007	19.6	29.8	24.7	0.0	0.0	0.0	0.0	0.0
9/06/2007	15.0	28.0	21.5	0.0	0.0	0.0	0.0	0.0
10/06/2007	15.4	27.9	21.6	0.0	0.0	0.0	0.0	0.0
11/06/2007	16.0	29.1	22.6	0.0	0.0	0.0	0.0	0.0
12/06/2007	17.9	30.0	23.9	0.0	0.0	0.0	0.0	0.0
13/06/2007	18.9	30.6	24.8	0.0	0.0	0.0	0.0	0.0
14/06/2007	20.6	32.0	26.3	0.0	0.0	0.0	0.0	0.0
15/06/2007	21.5	32.5	27.0	0.0	0.0	0.0	0.0	0.0
16/06/2007	21.9	32.4	27.2	0.0	0.0	0.0	0.0	0.0
17/06/2007	24.0	33.2	28.6	0.0	0.0	0.0	0.0	0.0
18/06/2007	23.6	31.4	27.5	0.0	0.0	0.0	0.0	0.0
19/06/2007	22.7	26.1	24.4	0.0	0.0	0.0	0.0	0.0
20/06/2007	18.3	22.7	20.5	0.0	0.0	0.0	0.0	0.0
21/06/2007	17.9	26.6	22.3	0.0	0.0	0.0	0.0	0.0
22/06/2007	19.5	25.9	22.7	0.0	0.0	0.0	0.0	0.0
23/06/2007	20.5	29.5	25.0	0.0	0.0	0.0	0.0	0.0
24/06/2007	20.9	31.6	26.3	0.0	0.0	0.0	0.0	0.0
25/06/2007	22.7	29.4	26.1	0.0	0.0	0.0	0.0	0.0
26/06/2007	20.7	29.0	24.9	0.0	0.0	0.0	0.0	0.0
27/06/2007	18.0	27.3	22.6	0.0	0.0	0.0	0.0	0.0
28/06/2007	15.2	27.0	21.1	0.0	0.0	0.0	0.0	0.0
29/06/2007	13.7	27.0	20.3	0.0	0.0	0.0	0.0	0.0
30/06/2007	12.4	28.2	20.3	0.0	0.0	0.0	0.0	0.0
1/07/2007	13.2	27.5	20.3	0.0	0.0	0.0	0.0	0.0
2/07/2007	14.2	29.2	21.7	0.0	0.0	0.0	0.0	0.0
3/07/2007	17.6	29.6	23.6	0.0	0.0	0.0	0.0	0.0

BC0704 Planting 2 – Darwin, NT

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
30/05/2007	23.9	33.2	28.6	0.0	0.0	0.0	0.0	0.0
31/05/2007	23.5	33.2	28.4	0.0	0.0	0.0	0.0	0.0
1/06/2007	24.6	32.0	28.3	0.0	0.0	0.0	0.0	0.0
2/06/2007	23.7	32.7	28.2	0.0	0.0	0.0	0.0	0.0
3/06/2007	23.5	33.3	28.4	0.0	0.0	0.0	0.0	0.0
4/06/2007	21.6	32.6	27.1	0.0	0.0	0.0	0.0	0.0
5/06/2007	22.0	33.1	27.5	0.0	0.0	0.0	0.0	0.0
6/06/2007	23.5	33.9	28.7	0.0	0.0	0.0	0.0	0.0
7/06/2007	23.4	32.8	28.1	0.0	0.0	0.0	0.0	0.0
8/06/2007	19.6	29.8	24.7	0.0	0.0	0.0	0.0	0.0
9/06/2007	15.0	28.0	21.5	0.0	0.0	0.0	0.0	0.0
10/06/2007	15.4	27.9	21.6	0.0	0.0	0.0	0.0	0.0
11/06/2007	16.0	29.1	22.6	0.0	0.0	0.0	0.0	0.0
12/06/2007	17.9	30.0	23.9	0.0	0.0	0.0	0.0	0.0
13/06/2007	18.9	30.6	24.8	0.0	0.0	0.0	0.0	0.0
14/06/2007	20.6	32.0	26.3	0.0	0.0	0.0	0.0	0.0
15/06/2007	21.5	32.5	27.0	0.0	0.0	0.0	0.0	0.0
16/06/2007	21.9	32.4	27.2	0.0	0.0	0.0	0.0	0.0
17/06/2007	24.0	33.2	28.6	0.0	0.0	0.0	0.0	0.0
18/06/2007	23.6	31.4	27.5	0.0	0.0	0.0	0.0	0.0
19/06/2007	22.7	26.1	24.4	0.0	0.0	0.0	0.0	0.0
20/06/2007	18.3	22.7	20.5	0.0	0.0	0.0	0.0	0.0
21/06/2007	17.9	26.6	22.3	0.0	0.0	0.0	0.0	0.0
22/06/2007	19.5	25.9	22.7	0.0	0.0	0.0	0.0	0.0
23/06/2007	20.5	29.5	25.0	0.0	0.0	0.0	0.0	0.0
24/06/2007	20.9	31.6	26.3	0.0	0.0	0.0	0.0	0.0
25/06/2007	22.7	29.4	26.1	0.0	0.0	0.0	0.0	0.0
26/06/2007	20.7	29.0	24.9	0.0	0.0	0.0	0.0	0.0
27/06/2007	18.0	27.3	22.6	0.0	0.0	0.0	0.0	0.0
28/06/2007	15.2	27.0	21.1	0.0	0.0	0.0	0.0	0.0
29/06/2007	13.7	27.0	20.3	0.0	0.0	0.0	0.0	0.0
30/06/2007	12.4	28.2	20.3	0.0	0.0	0.0	0.0	0.0
1/07/2007	13.2	27.5	20.3	0.0	0.0	0.0	0.0	0.0
2/07/2007	14.2	29.2	21.7	0.0	0.0	0.0	0.0	0.0
3/07/2007	17.6	29.6	23.6	0.0	0.0	0.0	0.0	0.0
4/07/2007	17.5	28.6	23.1	0.0	0.0	0.0	0.0	0.0
5/07/2007	16.9	30.9	23.9	0.0	0.0	0.0	0.0	0.0
6/07/2007	17.1	30.5	23.8	0.0	0.0	0.0	0.0	0.0
7/07/2007	16.5	29.6	23.1	0.0	0.0	0.0	0.0	0.0
8/07/2007	15.2	28.7	22.0	0.0	0.0	0.0	0.0	0.0
9/07/2007	14.8	27.3	21.0	0.0	0.0	0.0	0.0	0.0
10/07/2007	15.9	27.1	21.5	0.0	0.0	0.0	0.0	0.0
11/07/2007	14.8	27.8	21.3	0.0	0.0	0.0	0.0	0.0
12/07/2007	15.6	28.9	22.3	0.0	0.0	0.0	0.0	0.0
13/07/2007	16.9	29.9	23.4	0.0	0.0	0.0	0.0	0.0
14/07/2007	18.1	30.4	24.3	0.0	0.0	0.0	0.0	0.0
15/07/2007	19.3	31.1	25.2	0.0	0.0	0.0	0.0	0.0
16/07/2007	19.6	30.9	25.3	0.0	0.0	0.0	0.0	0.0
17/07/2007	19.4	31.1	25.3	0.0	0.0	0.0	0.0	0.0
18/07/2007	19.2	30.7	25.0	0.0	0.0	0.0	0.0	0.0
19/07/2007	19.2	31.0	25.1	0.0	0.0	0.0	0.0	0.0
20/07/2007	19.3	29.9	24.6	0.0	0.0	0.0	0.0	0.0
21/07/2007	17.3	29.2	23.3	0.0	0.0	0.0	0.0	0.0
22/07/2007	18.2	30.0	24.1	0.0	0.0	0.0	0.0	0.0
23/07/2007	17.2	30.4	23.8	0.0	0.0	0.0	0.0	0.0
24/07/2007	18.2	31.5	24.9	0.0	0.0	0.0	0.0	0.0

BC0704 Planting 3 – Darwin, NT

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
20/06/2007	18.3	22.7	20.5	0.0	0.0	0.0	0.0	0.0
21/06/2007	17.9	26.6	22.3	0.0	0.0	0.0	0.0	0.0
22/06/2007	19.5	25.9	22.7	0.0	0.0	0.0	0.0	0.0
23/06/2007	20.5	29.5	25.0	0.0	0.0	0.0	0.0	0.0
24/06/2007	20.9	31.6	26.3	0.0	0.0	0.0	0.0	0.0
25/06/2007	22.7	29.4	26.1	0.0	0.0	0.0	0.0	0.0
26/06/2007	20.7	29.0	24.9	0.0	0.0	0.0	0.0	0.0
27/06/2007	18.0	27.3	22.6	0.0	0.0	0.0	0.0	0.0
28/06/2007	15.2	27.0	21.1	0.0	0.0	0.0	0.0	0.0
29/06/2007	13.7	27.0	20.3	0.0	0.0	0.0	0.0	0.0
30/06/2007	12.4	28.2	20.3	0.0	0.0	0.0	0.0	0.0
1/07/2007	13.2	27.5	20.3	0.0	0.0	0.0	0.0	0.0
2/07/2007	14.2	29.2	21.7	0.0	0.0	0.0	0.0	0.0
3/07/2007	17.6	29.6	23.6	0.0	0.0	0.0	0.0	0.0
4/07/2007	17.5	28.6	23.1	0.0	0.0	0.0	0.0	0.0
5/07/2007	16.9	30.9	23.9	0.0	0.0	0.0	0.0	0.0
6/07/2007	17.1	30.5	23.8	0.0	0.0	0.0	0.0	0.0
7/07/2007	16.5	29.6	23.1	0.0	0.0	0.0	0.0	0.0
8/07/2007	15.2	28.7	22.0	0.0	0.0	0.0	0.0	0.0
9/07/2007	14.8	27.3	21.0	0.0	0.0	0.0	0.0	0.0
10/07/2007	15.9	27.1	21.5	0.0	0.0	0.0	0.0	0.0
11/07/2007	14.8	27.8	21.3	0.0	0.0	0.0	0.0	0.0
12/07/2007	15.6	28.9	22.3	0.0	0.0	0.0	0.0	0.0
13/07/2007	16.9	29.9	23.4	0.0	0.0	0.0	0.0	0.0
14/07/2007	18.1	30.4	24.3	0.0	0.0	0.0	0.0	0.0
15/07/2007	19.3	31.1	25.2	0.0	0.0	0.0	0.0	0.0
16/07/2007	19.6	30.9	25.3	0.0	0.0	0.0	0.0	0.0
17/07/2007	19.4	31.1	25.3	0.0	0.0	0.0	0.0	0.0
18/07/2007	19.2	30.7	25.0	0.0	0.0	0.0	0.0	0.0
19/07/2007	19.2	31.0	25.1	0.0	0.0	0.0	0.0	0.0
20/07/2007	19.3	29.9	24.6	0.0	0.0	0.0	0.0	0.0
21/07/2007	17.3	29.2	23.3	0.0	0.0	0.0	0.0	0.0
22/07/2007	18.2	30.0	24.1	0.0	0.0	0.0	0.0	0.0
23/07/2007	17.2	30.4	23.8	0.0	0.0	0.0	0.0	0.0
24/07/2007	18.2	31.5	24.9	0.0	0.0	0.0	0.0	0.0
25/07/2007	18.4	30.8	24.6	0.0	0.0	0.0	0.0	0.0
26/07/2007	20.1	31.0	25.6	0.0	0.0	0.0	0.0	0.0
27/07/2007	18.9	31.6	25.3	0.0	0.0	0.0	0.0	0.0
28/07/2007	19.7	29.6	24.7	0.0	0.0	0.0	0.0	0.0
29/07/2007	18.7	29.4	24.1	0.0	0.0	0.0	0.0	0.0
30/07/2007	18.7	29.4	24.1	0.0	0.0	0.0	0.0	0.0
31/07/2007	18.2	32.0	25.1	0.0	0.0	0.0	0.0	0.0
1/08/2007	18.8	29.6	24.2	0.0	0.0	0.0	0.0	0.0
2/08/2007	18.9	29.0	23.9	0.0	0.0	0.0	0.0	0.0
3/08/2007	19.4	28.8	24.1	0.0	0.0	0.0	0.0	0.0
4/08/2007	20.1	29.7	24.9	0.0	0.0	0.0	0.0	0.0
5/08/2007	19.3	31.3	25.3	0.0	0.0	0.0	0.0	0.0
6/08/2007	17.7	30.8	24.3	0.0	0.0	0.0	0.0	0.0
7/08/2007	16.4	30.3	23.3	0.0	0.0	0.0	0.0	0.0
8/08/2007	17.7	30.0	23.9	0.0	0.0	0.0	0.0	0.0
9/08/2007	17.6	31.8	24.7	0.0	0.0	0.0	0.0	0.0
10/08/2007	18.8	32.4	25.6	0.0	0.0	0.0	0.0	0.0
11/08/2007	20.2	31.6	25.9	0.0	0.0	0.0	0.0	0.0
12/08/2007	19.0	30.8	24.9	0.0	0.0	0.0	0.0	0.0
13/08/2007	20.9	30.9	25.9	0.0	0.0	0.0	0.0	0.0
14/08/2007	21.3	32.5	26.9	0.0	0.0	0.0	0.0	0.0

BC0705 Planting 1 – Clyde, Vic

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
26/10/2007	11.0	23.0	17.0	0.0	0.0	0.0	0.0	0.0
27/10/2007	9.4	27.5	18.4	0.0	0.0	0.0	0.0	0.0
28/10/2007	15.4	27.5	21.4	0.0	0.0	0.0	0.0	0.0
29/10/2007	10.2	20.0	15.1	15.1	8.6	-0.3	0.7	0.7
30/10/2007	9.0	21.1	15.1	15.1	8.6	-0.3	0.7	1.5
31/10/2007	9.4	19.0	14.2	14.2	7.7	0.4	0.4	1.9
1/11/2007	11.0	24.1	17.6	0.0	0.0	0.0	0.0	1.9
2/11/2007	12.4	19.1	15.8	15.8	9.3	-0.8	0.2	2.1
3/11/2007	12.5	18.1	15.3	15.3	8.8	-0.4	0.6	2.6
4/11/2007	11.0	12.2	11.6	11.6	5.1	2.5	2.5	5.1
5/11/2007	8.0	15.8	11.9	11.9	5.4	2.2	2.2	7.3
6/11/2007	8.9	19.3	14.1	14.1	7.6	0.5	0.5	7.8
7/11/2007	10.0	19.4	14.7	14.7	8.2	0.0	0.0	7.9
8/11/2007	9.5	20.6	15.1	15.1	8.6	-0.3	0.7	8.6
9/11/2007	6.5	24.6	15.6	15.6	9.1	-0.6	0.4	9.0
10/11/2007	9.8	25.1	17.5	0.0	0.0	0.0	0.0	9.0
11/11/2007	10.3	24.6	17.5	0.0	0.0	0.0	0.0	9.0
12/11/2007	10.4	18.2	14.3	14.3	7.8	0.3	0.3	9.3
13/11/2007	12.1	20.1	16.1	0.0	0.0	0.0	0.0	9.3
14/11/2007	12.6	21.2	16.9	0.0	0.0	0.0	0.0	9.3
15/11/2007	10.2	22.0	16.1	0.0	0.0	0.0	0.0	9.3
16/11/2007	9.0	29.0	19.0	0.0	0.0	0.0	0.0	9.3
17/11/2007	13.5	26.5	20.0	0.0	0.0	0.0	0.0	9.3
18/11/2007	13.0	30.0	21.5	0.0	0.0	0.0	0.0	9.3
19/11/2007	17.0	33.4	25.2	0.0	0.0	0.0	0.0	9.3
20/11/2007	18.0	34.1	26.0	0.0	0.0	0.0	0.0	9.3
21/11/2007	12.5	14.5	13.5	13.5	7.0	1.0	1.0	10.3
22/11/2007	9.0	17.0	13.0	13.0	6.5	1.4	1.4	11.7
23/11/2007	11.4	18.4	14.9	14.9	8.4	-0.1	0.9	12.5
24/11/2007	10.1	21.5	15.8	15.8	9.3	-0.8	0.2	12.7
25/11/2007	13.1	18.8	15.9	15.9	9.4	-1.0	0.0	12.7
26/11/2007	11.6	25.0	18.3	0.0	0.0	0.0	0.0	12.7
27/11/2007	12.8	26.0	19.4	0.0	0.0	0.0	0.0	12.7
28/11/2007	14.6	28.0	21.3	0.0	0.0	0.0	0.0	12.7
29/11/2007	15.0	26.0	20.5	0.0	0.0	0.0	0.0	12.7
30/11/2007	14.0	26.2	20.1	0.0	0.0	0.0	0.0	12.7
1/12/2007	14.5	26.5	20.5	0.0	0.0	0.0	0.0	12.7
2/12/2007	12.0	31.7	21.9	0.0	0.0	0.0	0.0	12.7
3/12/2007	17.0	23.0	20.0	0.0	0.0	0.0	0.0	12.7
4/12/2007	12.1	22.3	17.2	0.0	0.0	0.0	0.0	12.7
5/12/2007	13.2	22.5	17.8	0.0	0.0	0.0	0.0	12.7
6/12/2007	13.0	32.5	22.8	0.0	0.0	0.0	0.0	12.7
7/12/2007	17.0	24.1	20.6	0.0	0.0	0.0	0.0	12.7
8/12/2007	9.4	23.3	16.3	0.0	0.0	0.0	0.0	12.7
9/12/2007	12.1	24.0	18.1	0.0	0.0	0.0	0.0	12.7
10/12/2007	7.6	17.8	12.7	12.7	6.2	1.6	1.6	14.3
11/12/2007	7.8	20.9	14.3	14.3	7.8	0.3	0.3	14.6
12/12/2007	10.2	24.0	17.1	0.0	0.0	0.0	0.0	14.6
13/12/2007	13.2	29.0	21.1	0.0	0.0	0.0	0.0	14.6
14/12/2007	13.5	32.6	23.0	0.0	0.0	0.0	0.0	14.6
15/12/2007	15.5	17.4	16.4	0.0	0.0	0.0	0.0	14.6
16/12/2007	11.4	19.3	15.3	15.3	8.8	-0.5	0.5	15.1
17/12/2007	12.0	25.4	18.7	0.0	0.0	0.0	0.0	15.1
18/12/2007	13.2	26.1	19.7	0.0	0.0	0.0	0.0	15.1
19/12/2007	14.0	29.0	21.5	0.0	0.0	0.0	0.0	15.1
20/12/2007	16.0	26.5	21.3	0.0	0.0	0.0	0.0	15.1

BC0705 Planting 2 – Clyde, Vic

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
29/10/2007	10.2	20.0	15.1	15.1	8.6	-0.3	0.7	0.7
30/10/2007	9.0	21.1	15.1	15.1	8.6	-0.3	0.7	1.5
31/10/2007	9.4	19.0	14.2	14.2	7.7	0.4	0.4	1.9
1/11/2007	11.0	24.1	17.6	0.0	0.0	0.0	0.0	1.9
2/11/2007	12.4	19.1	15.8	15.8	9.3	-0.8	0.2	2.1
3/11/2007	12.5	18.1	15.3	15.3	8.8	-0.4	0.6	2.6
4/11/2007	11.0	12.2	11.6	11.6	5.1	2.5	2.5	5.1
5/11/2007	8.0	15.8	11.9	11.9	5.4	2.2	2.2	7.3
6/11/2007	8.9	19.3	14.1	14.1	7.6	0.5	0.5	7.8
7/11/2007	10.0	19.4	14.7	14.7	8.2	0.0	0.0	7.9
8/11/2007	9.5	20.6	15.1	15.1	8.6	-0.3	0.7	8.6
9/11/2007	6.5	24.6	15.6	15.6	9.1	-0.6	0.4	9.0
10/11/2007	9.8	25.1	17.5	0.0	0.0	0.0	0.0	9.0
11/11/2007	10.3	24.6	17.5	0.0	0.0	0.0	0.0	9.0
12/11/2007	10.4	18.2	14.3	14.3	7.8	0.3	0.3	9.3
13/11/2007	12.1	20.1	16.1	0.0	0.0	0.0	0.0	9.3
14/11/2007	12.6	21.2	16.9	0.0	0.0	0.0	0.0	9.3
15/11/2007	10.2	22.0	16.1	0.0	0.0	0.0	0.0	9.3
16/11/2007	9.0	29.0	19.0	0.0	0.0	0.0	0.0	9.3
17/11/2007	13.5	26.5	20.0	0.0	0.0	0.0	0.0	9.3
18/11/2007	13.0	30.0	21.5	0.0	0.0	0.0	0.0	9.3
19/11/2007	17.0	33.4	25.2	0.0	0.0	0.0	0.0	9.3
20/11/2007	18.0	34.1	26.0	0.0	0.0	0.0	0.0	9.3
21/11/2007	12.5	14.5	13.5	13.5	7.0	1.0	1.0	10.3
22/11/2007	9.0	17.0	13.0	13.0	6.5	1.4	1.4	11.7
23/11/2007	11.4	18.4	14.9	14.9	8.4	-0.1	0.9	12.5
24/11/2007	10.1	21.5	15.8	15.8	9.3	-0.8	0.2	12.7
25/11/2007	13.1	18.8	15.9	15.9	9.4	-1.0	0.0	12.7
26/11/2007	11.6	25.0	18.3	0.0	0.0	0.0	0.0	12.7
27/11/2007	12.8	26.0	19.4	0.0	0.0	0.0	0.0	12.7
28/11/2007	14.6	28.0	21.3	0.0	0.0	0.0	0.0	12.7
29/11/2007	15.0	26.0	20.5	0.0	0.0	0.0	0.0	12.7
30/11/2007	14.0	26.2	20.1	0.0	0.0	0.0	0.0	12.7
1/12/2007	14.5	26.5	20.5	0.0	0.0	0.0	0.0	12.7
2/12/2007	12.0	31.7	21.9	0.0	0.0	0.0	0.0	12.7
3/12/2007	17.0	23.0	20.0	0.0	0.0	0.0	0.0	12.7
4/12/2007	12.1	22.3	17.2	0.0	0.0	0.0	0.0	12.7
5/12/2007	13.2	22.5	17.8	0.0	0.0	0.0	0.0	12.7
6/12/2007	13.0	32.5	22.8	0.0	0.0	0.0	0.0	12.7
7/12/2007	17.0	24.1	20.6	0.0	0.0	0.0	0.0	12.7
8/12/2007	9.4	23.3	16.3	0.0	0.0	0.0	0.0	12.7
9/12/2007	12.1	24.0	18.1	0.0	0.0	0.0	0.0	12.7
10/12/2007	7.6	17.8	12.7	12.7	6.2	1.6	1.6	14.3
11/12/2007	7.8	20.9	14.3	14.3	7.8	0.3	0.3	14.6
12/12/2007	10.2	24.0	17.1	0.0	0.0	0.0	0.0	14.6
13/12/2007	13.2	29.0	21.1	0.0	0.0	0.0	0.0	14.6
14/12/2007	13.5	32.6	23.0	0.0	0.0	0.0	0.0	14.6
15/12/2007	15.5	17.4	16.4	0.0	0.0	0.0	0.0	14.6
16/12/2007	11.4	19.3	15.3	15.3	8.8	-0.5	0.5	15.1
17/12/2007	12.0	25.4	18.7	0.0	0.0	0.0	0.0	15.1
18/12/2007	13.2	26.1	19.7	0.0	0.0	0.0	0.0	15.1
19/12/2007	14.0	29.0	21.5	0.0	0.0	0.0	0.0	15.1
20/12/2007	16.0	26.5	21.3	0.0	0.0	0.0	0.0	15.1
21/12/2007	16.5	26.4	21.5	0.0	0.0	0.0	0.0	15.1
22/12/2007	16.1	17.0	16.6	0.0	0.0	0.0	0.0	15.1
23/12/2007	9.8	18.5	14.2	14.2	7.7	0.5	0.5	15.6

Data from nearby alternative station

BC0706 – Clyde, Vic

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
8/11/2007	9.5	20.6	15.1	15.1	8.6	-0.3	0.7	0.7
9/11/2007	6.5	24.6	15.6	15.6	9.1	-0.6	0.4	1.1
10/11/2007	9.8	25.1	17.5	0.0	0.0	0.0	0.0	1.1
11/11/2007	10.3	24.6	17.5	0.0	0.0	0.0	0.0	1.1
12/11/2007	10.4	18.2	14.3	14.3	7.8	0.3	0.3	1.4
13/11/2007	12.1	20.1	16.1	0.0	0.0	0.0	0.0	1.4
14/11/2007	12.6	21.2	16.9	0.0	0.0	0.0	0.0	1.4
15/11/2007	10.2	22.0	16.1	0.0	0.0	0.0	0.0	1.4
16/11/2007	9.0	29.0	19.0	0.0	0.0	0.0	0.0	1.4
17/11/2007	13.5	26.5	20.0	0.0	0.0	0.0	0.0	1.4
18/11/2007	13.0	30.0	21.5	0.0	0.0	0.0	0.0	1.4
19/11/2007	17.0	33.4	25.2	0.0	0.0	0.0	0.0	1.4
20/11/2007	18.0	34.1	26.0	0.0	0.0	0.0	0.0	1.4
21/11/2007	12.5	14.5	13.5	13.5	7.0	1.0	1.0	2.4
22/11/2007	9.0	17.0	13.0	13.0	6.5	1.4	1.4	3.8
23/11/2007	11.4	18.4	14.9	14.9	8.4	-0.1	0.9	4.7
24/11/2007	10.1	21.5	15.8	15.8	9.3	-0.8	0.2	4.8
25/11/2007	13.1	18.8	15.9	15.9	9.4	-1.0	0.0	4.9
26/11/2007	11.6	25.0	18.3	0.0	0.0	0.0	0.0	4.9
27/11/2007	12.8	26.0	19.4	0.0	0.0	0.0	0.0	4.9
28/11/2007	14.6	28.0	21.3	0.0	0.0	0.0	0.0	4.9
29/11/2007	15.0	26.0	20.5	0.0	0.0	0.0	0.0	4.9
30/11/2007	14.0	26.2	20.1	0.0	0.0	0.0	0.0	4.9
1/12/2007	14.5	26.5	20.5	0.0	0.0	0.0	0.0	4.9
2/12/2007	12.0	31.7	21.9	0.0	0.0	0.0	0.0	4.9
3/12/2007	17.0	23.0	20.0	0.0	0.0	0.0	0.0	4.9
4/12/2007	12.1	22.3	17.2	0.0	0.0	0.0	0.0	4.9
5/12/2007	13.2	22.5	17.8	0.0	0.0	0.0	0.0	4.9
6/12/2007	13.0	32.5	22.8	0.0	0.0	0.0	0.0	4.9
7/12/2007	17.0	24.1	20.6	0.0	0.0	0.0	0.0	4.9
8/12/2007	9.4	23.3	16.3	0.0	0.0	0.0	0.0	4.9
9/12/2007	12.1	24.0	18.1	0.0	0.0	0.0	0.0	4.9
10/12/2007	7.6	17.8	12.7	12.7	6.2	1.6	1.6	6.5
11/12/2007	7.8	20.9	14.3	14.3	7.8	0.3	0.3	6.8
12/12/2007	10.2	24.0	17.1	0.0	0.0	0.0	0.0	6.8
13/12/2007	13.2	29.0	21.1	0.0	0.0	0.0	0.0	6.8
14/12/2007	13.5	32.6	23.0	0.0	0.0	0.0	0.0	6.8
15/12/2007	15.5	17.4	16.4	0.0	0.0	0.0	0.0	6.8
16/12/2007	11.4	19.3	15.3	15.3	8.8	-0.5	0.5	7.3
17/12/2007	12.0	25.4	18.7	0.0	0.0	0.0	0.0	7.3
18/12/2007	13.2	26.1	19.7	0.0	0.0	0.0	0.0	7.3
19/12/2007	14.0	29.0	21.5	0.0	0.0	0.0	0.0	7.3
20/12/2007	16.0	26.5	21.3	0.0	0.0	0.0	0.0	7.3
21/12/2007	16.5	26.4	21.5	0.0	0.0	0.0	0.0	7.3
22/12/2007	16.1	17.0	16.6	0.0	0.0	0.0	0.0	7.3
23/12/2007	9.8	18.5	14.2	14.2	7.7	0.5	0.5	7.7
24/12/2007	12.7	17.9	15.3	15.3	8.8	-0.4	0.6	8.3
25/12/2007	8.8	18.5	13.7	13.7	7.2	0.9	0.9	9.1
26/12/2007	7.5	23.0	15.3	15.3	8.8	-0.4	0.6	9.7
27/12/2007	11.0	22.1	16.6	0.0	0.0	0.0	0.0	9.7
28/12/2007	11.4	33.8	22.6	0.0	0.0	0.0	0.0	9.7
29/12/2007	17.7	38.0	27.9	0.0	0.0	0.0	0.0	9.7
30/12/2007	13.2	28.3	20.7	0.0	0.0	0.0	0.0	9.7
31/12/2007	14.8	38.9	26.9	0.0	0.0	0.0	0.0	9.7
1/01/2008	19.9	38.0	28.9	0.0	0.0	0.0	0.0	9.7
2/01/2008	12.0	26.3	19.1	0.0	0.0	0.0	0.0	9.7

Data from nearby alternative station

BC0707 – Parilla, SA

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
19/09/2007	13.0	22.4	17.7	0.0	0.0	0.0	0.0	0.0
20/09/2007	2.3	18.3	10.3	10.3	3.8	3.5	3.5	3.5
21/09/2007	2.1	23.1	12.6	12.6	6.1	1.7	1.7	5.2
22/09/2007	7.3	24.4	15.8	15.8	9.3	-0.9	0.1	5.3
23/09/2007	10.4	27.2	18.8	0.0	0.0	0.0	0.0	5.3
24/09/2007	4.4	19.3	11.8	11.8	5.3	2.3	2.3	7.6
25/09/2007	4.6	27.8	16.2	0.0	0.0	0.0	0.0	7.6
26/09/2007	11.5	18.2	14.9	14.9	8.4	-0.1	0.9	8.5
27/09/2007	8.7	21.2	15.0	15.0	8.5	-0.2	0.8	9.3
28/09/2007	8.9	16.0	12.4	12.4	5.9	1.8	1.8	11.1
29/09/2007	5.5	18.9	12.2	12.2	5.7	2.0	2.0	13.1
30/09/2007	9.0	21.9	15.4	15.4	8.9	-0.6	0.4	13.6
1/10/2007	8.0	22.6	15.3	15.3	8.8	-0.4	0.6	14.1
2/10/2007	3.1	31.3	17.2	0.0	0.0	0.0	0.0	14.1
3/10/2007	9.0	20.4	14.7	14.7	8.2	0.0	0.0	14.1
4/10/2007	3.0	22.0	12.5	12.5	6.0	1.8	1.8	15.9
5/10/2007	4.0	25.6	14.8	14.8	8.3	-0.1	0.9	16.8
6/10/2007	3.9	19.0	11.5	11.5	5.0	2.6	2.6	19.4
7/10/2007	6.2	18.0	12.1	12.1	5.6	2.1	2.1	21.5
8/10/2007	0.9	19.2	10.1	10.1	3.6	3.7	3.7	25.2
9/10/2007	3.1	22.9	13.0	13.0	6.5	1.4	1.4	26.6
10/10/2007	10.0	29.1	19.6	0.0	0.0	0.0	0.0	26.6
11/10/2007	6.9	17.5	12.2	12.2	5.7	2.0	2.0	28.6
12/10/2007	3.4	16.3	9.8	9.8	3.3	3.9	3.9	32.4
13/10/2007	6.6	18.5	12.5	12.5	6.0	1.7	1.7	34.2
14/10/2007	4.6	24.7	14.7	14.7	8.2	0.1	0.1	34.2
15/10/2007	7.3	32.3	19.8	0.0	0.0	0.0	0.0	34.2
16/10/2007	8.8	19.6	14.2	14.2	7.7	0.4	0.4	34.6
17/10/2007	2.0	22.8	12.4	12.4	5.9	1.8	1.8	36.5
18/10/2007	5.5	30.7	18.1	0.0	0.0	0.0	0.0	36.5
19/10/2007	5.5	24.4	14.9	14.9	8.4	-0.2	0.8	37.3
20/10/2007	6.2	32.7	19.5	0.0	0.0	0.0	0.0	37.3
21/10/2007	15.3	38.2	26.8	0.0	0.0	0.0	0.0	37.3
22/10/2007	16.0	24.4	20.2	0.0	0.0	0.0	0.0	37.3
23/10/2007	12.1	18.7	15.4	15.4	8.9	-0.5	0.5	37.8
24/10/2007	4.8	21.4	13.1	13.1	6.6	1.3	1.3	39.1
25/10/2007	8.7	20.9	14.8	14.8	8.3	-0.1	0.9	40.0
26/10/2007	6.1	27.1	16.6	0.0	0.0	0.0	0.0	40.0
27/10/2007	9.6	33.6	21.6	0.0	0.0	0.0	0.0	40.0
28/10/2007	12.5	22.0	17.3	0.0	0.0	0.0	0.0	40.0
29/10/2007	4.8	22.0	13.4	13.4	6.9	1.1	1.1	41.1
30/10/2007	4.9	23.0	14.0	14.0	7.5	0.6	0.6	41.7
31/10/2007	11.9	21.2	16.6	0.0	0.0	0.0	0.0	41.7
1/11/2007	10.3	27.5	18.9	0.0	0.0	0.0	0.0	41.7
2/11/2007	14.1	21.1	17.6	0.0	0.0	0.0	0.0	41.7
3/11/2007	13.0	16.3	14.6	14.6	8.1	0.1	0.1	41.8
4/11/2007	8.9	16.3	12.6	12.6	6.1	1.7	1.7	43.4
5/11/2007	6.5	22.5	14.5	14.5	8.0	0.2	0.2	43.6
6/11/2007	7.2	24.4	15.8	15.8	9.3	-0.8	0.2	43.8
7/11/2007	10.3	26.4	18.3	0.0	0.0	0.0	0.0	43.8
8/11/2007	13.7	27.0	20.3	0.0	0.0	0.0	0.0	43.8
9/11/2007	11.4	30.1	20.8	0.0	0.0	0.0	0.0	43.8
10/11/2007	13.0	32.0	22.5	0.0	0.0	0.0	0.0	43.8
11/11/2007	11.7	32.8	22.2	0.0	0.0	0.0	0.0	43.8
12/11/2007	9.1	32.0	20.6	0.0	0.0	0.0	0.0	43.8
13/11/2007	12.3	34.4	23.4	0.0	0.0	0.0	0.0	43.8

BC0801 – Dareton, NSW

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
23/01/2008	18.0	35.0	26.5	0.0	0.0	0.0	0.0	0.0
24/01/2008	21.0	32.5	26.8	0.0	0.0	0.0	0.0	0.0
25/01/2008	19.5	38.5	29.0	0.0	0.0	0.0	0.0	0.0
26/01/2008	23.0	38.8	30.9	0.0	0.0	0.0	0.0	0.0
27/01/2008	20.0	35.5	27.8	0.0	0.0	0.0	0.0	0.0
28/01/2008	15.0	36.5	25.8	0.0	0.0	0.0	0.0	0.0
29/01/2008	20.0	39.5	29.8	0.0	0.0	0.0	0.0	0.0
30/01/2008	22.0	40.0	31.0	0.0	0.0	0.0	0.0	0.0
31/01/2008	24.0	34.0	29.0	0.0	0.0	0.0	0.0	0.0
1/02/2008	21.0	35.0	28.0	0.0	0.0	0.0	0.0	0.0
2/02/2008	15.0	38.5	26.8	0.0	0.0	0.0	0.0	0.0
3/02/2008	20.0	39.0	29.5	0.0	0.0	0.0	0.0	0.0
4/02/2008	22.0	38.7	30.4	0.0	0.0	0.0	0.0	0.0
5/02/2008	21.5	39.0	30.3	0.0	0.0	0.0	0.0	0.0
6/02/2008	22.0	28.0	25.0	0.0	0.0	0.0	0.0	0.0
7/02/2008	10.0	27.0	18.5	0.0	0.0	0.0	0.0	0.0
8/02/2008	10.0	25.0	17.5	0.0	0.0	0.0	0.0	0.0
9/02/2008	11.0	26.8	18.9	0.0	0.0	0.0	0.0	0.0
10/02/2008	13.0	29.0	21.0	0.0	0.0	0.0	0.0	0.0
11/02/2008	15.0	34.0	24.5	0.0	0.0	0.0	0.0	0.0
12/02/2008	22.0	34.5	28.3	0.0	0.0	0.0	0.0	0.0
13/02/2008	13.0	29.5	21.3	0.0	0.0	0.0	0.0	0.0
14/02/2008	13.0	33.0	23.0	0.0	0.0	0.0	0.0	0.0
15/02/2008	17.0	38.0	27.5	0.0	0.0	0.0	0.0	0.0
16/02/2008	20.5	38.0	29.3	0.0	0.0	0.0	0.0	0.0
17/02/2008	21.5	37.0	29.3	0.0	0.0	0.0	0.0	0.0
18/02/2008	20.5	37.0	28.8	0.0	0.0	0.0	0.0	0.0
19/02/2008	21.0	37.5	29.3	0.0	0.0	0.0	0.0	0.0
20/02/2008	21.0	31.5	26.3	0.0	0.0	0.0	0.0	0.0
21/02/2008	18.5	32.5	25.5	0.0	0.0	0.0	0.0	0.0
22/02/2008	20.5	25.0	22.8	0.0	0.0	0.0	0.0	0.0
23/02/2008	11.0	28.5	19.8	0.0	0.0	0.0	0.0	0.0
24/02/2008	13.0	28.0	20.5	0.0	0.0	0.0	0.0	0.0
25/02/2008	12.0	31.0	21.5	0.0	0.0	0.0	0.0	0.0
26/02/2008	15.0	32.5	23.8	0.0	0.0	0.0	0.0	0.0
27/02/2008	15.5	30.0	22.8	0.0	0.0	0.0	0.0	0.0
28/02/2008	12.0	26.5	19.3	0.0	0.0	0.0	0.0	0.0
29/02/2008	9.0	26.0	17.5	0.0	0.0	0.0	0.0	0.0
1/03/2008	11.0	30.0	20.5	0.0	0.0	0.0	0.0	0.0
2/03/2008	10.0	33.5	21.8	0.0	0.0	0.0	0.0	0.0
3/03/2008	16.0	36.5	26.3	0.0	0.0	0.0	0.0	0.0
4/03/2008	18.0	36.5	27.3	0.0	0.0	0.0	0.0	0.0
5/03/2008	18.0	37.5	27.8	0.0	0.0	0.0	0.0	0.0
6/03/2008	18.0	41.0	29.5	0.0	0.0	0.0	0.0	0.0
7/03/2008	20.0	38.5	29.3	0.0	0.0	0.0	0.0	0.0
8/03/2008	20.0	41.5	30.8	0.0	0.0	0.0	0.0	0.0
9/03/2008	20.5	40.0	30.3	0.0	0.0	0.0	0.0	0.0
10/03/2008	21.0	42.0	31.5	0.0	0.0	0.0	0.0	0.0
11/03/2008	22.0	42.0	32.0	0.0	0.0	0.0	0.0	0.0
12/03/2008	22.0	41.5	31.8	0.0	0.0	0.0	0.0	0.0
13/03/2008	24.0	42.0	33.0	0.0	0.0	0.0	0.0	0.0
14/03/2008	24.5	40.0	32.3	0.0	0.0	0.0	0.0	0.0
15/03/2008	22.5	42.0	32.3	0.0	0.0	0.0	0.0	0.0
16/03/2008	23.0	42.0	32.5	0.0	0.0	0.0	0.0	0.0
17/03/2008	23.0	40.0	31.5	0.0	0.0	0.0	0.0	0.0
18/03/2008	22.0	37.5	29.8	0.0	0.0	0.0	0.0	0.0

BC0804 Planting 1 – Dareton, NSW

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
19/03/2008	22.0	31.0	26.5	0.0	0.0	0.0	0.0	0.0
20/03/2008	17.0	28.0	22.5	0.0	0.0	0.0	0.0	0.0
21/03/2008	10.0	25.5	17.8	0.0	0.0	0.0	0.0	0.0
22/03/2008	9.5	29.0	19.3	0.0	0.0	0.0	0.0	0.0
23/03/2008	23.5	33.5	28.5	0.0	0.0	0.0	0.0	0.0
24/03/2008	19.0	31.5	25.3	0.0	0.0	0.0	0.0	0.0
25/03/2008	18.0	26.0	22.0	0.0	0.0	0.0	0.0	0.0
26/03/2008	12.0	23.0	17.5	0.0	0.0	0.0	0.0	0.0
27/03/2008	11.0	21.0	16.0	16.0	9.5	-1.0	0.0	0.0
28/03/2008	15.0	21.0	18.0	0.0	0.0	0.0	0.0	0.0
29/03/2008	9.0	24.0	16.5	0.0	0.0	0.0	0.0	0.0
30/03/2008	11.0	23.0	17.0	0.0	0.0	0.0	0.0	0.0
31/03/2008	11.5	24.0	17.8	0.0	0.0	0.0	0.0	0.0
1/04/2008	10.0	28.0	19.0	0.0	0.0	0.0	0.0	0.0
2/04/2008	15.0	29.0	22.0	0.0	0.0	0.0	0.0	0.0
3/04/2008	13.0	18.5	15.8	15.8	9.3	-0.8	0.2	0.2
4/04/2008	12.0	22.0	17.0	0.0	0.0	0.0	0.0	0.2
5/04/2008	8.0	25.0	16.5	0.0	0.0	0.0	0.0	0.2
6/04/2008	12.0	24.5	18.3	0.0	0.0	0.0	0.0	0.2
7/04/2008	8.0	29.0	18.5	0.0	0.0	0.0	0.0	0.2
8/04/2008	12.0	30.0	21.0	0.0	0.0	0.0	0.0	0.2
9/04/2008	15.0	28.0	21.5	0.0	0.0	0.0	0.0	0.2
10/04/2008	15.0	30.5	22.8	0.0	0.0	0.0	0.0	0.2
11/04/2008	18.0	29.5	23.8	0.0	0.0	0.0	0.0	0.2
12/04/2008	12.0	23.0	17.5	0.0	0.0	0.0	0.0	0.2
13/04/2008	8.0	21.0	14.5	14.5	8.0	0.2	0.2	0.4
14/04/2008	12.0	22.5	17.3	0.0	0.0	0.0	0.0	0.4
15/04/2008	9.0	25.0	17.0	0.0	0.0	0.0	0.0	0.4
16/04/2008	9.0	25.5	17.3	0.0	0.0	0.0	0.0	0.4
17/04/2008	7.0	26.5	16.8	0.0	0.0	0.0	0.0	0.4
18/04/2008	9.0	28.0	18.5	0.0	0.0	0.0	0.0	0.4
19/04/2008	11.0	28.0	19.5	0.0	0.0	0.0	0.0	0.4
20/04/2008	13.0	28.0	20.5	0.0	0.0	0.0	0.0	0.4
21/04/2008	12.0	26.5	19.3	0.0	0.0	0.0	0.0	0.4
22/04/2008	12.0	26.0	19.0	0.0	0.0	0.0	0.0	0.4
23/04/2008	14.0	28.0	21.0	0.0	0.0	0.0	0.0	0.4
24/04/2008	11.0	27.0	19.0	0.0	0.0	0.0	0.0	0.4
25/04/2008	10.0	29.0	19.5	0.0	0.0	0.0	0.0	0.4
26/04/2008	11.0	22.5	16.8	0.0	0.0	0.0	0.0	0.4
27/04/2008	8.0	13.0	10.5	10.5	4.0	3.3	3.3	3.7
28/04/2008	5.0	17.0	11.0	11.0	4.5	2.9	2.9	6.7
29/04/2008	3.0	18.5	10.8	10.8	4.3	3.1	3.1	9.8
30/04/2008	6.0	18.7	12.4	12.4	5.9	1.9	1.9	11.7
1/05/2008	9.0	20.0	14.5	14.5	8.0	0.2	0.2	11.9
2/05/2008	13.0	20.5	16.8	0.0	0.0	0.0	0.0	11.9
3/05/2008	8.5	20.0	14.3	14.3	7.8	0.4	0.4	12.3
4/05/2008	8.0	23.0	15.5	15.5	9.0	-0.6	0.4	12.7
5/05/2008	10.0	24.0	17.0	0.0	0.0	0.0	0.0	12.7
6/05/2008	10.0	21.5	15.8	15.8	9.3	-0.8	0.2	12.9
7/05/2008	11.0	20.0	15.5	15.5	9.0	-0.6	0.4	13.3
8/05/2008	6.0	21.0	13.5	13.5	7.0	1.0	1.0	14.2
9/05/2008	10.0	22.5	16.3	0.0	0.0	0.0	0.0	14.2
10/05/2008	5.0	20.5	12.8	12.8	6.3	1.6	1.6	15.8
11/05/2008	12.5	23.0	17.8	0.0	0.0	0.0	0.0	15.8
12/05/2008	7.0	23.5	15.3	15.3	8.8	-0.4	0.6	16.4
13/05/2008	8.0	24.5	16.3	0.0	0.0	0.0	0.0	16.4

BC0804 Planting 2 – Dareton, NSW

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
3/04/2008	13.0	18.5	15.8	15.8	9.3	-0.8	0.2	0.2
4/04/2008	12.0	22.0	17.0	0.0	0.0	0.0	0.0	0.2
5/04/2008	8.0	25.0	16.5	0.0	0.0	0.0	0.0	0.2
6/04/2008	12.0	24.5	18.3	0.0	0.0	0.0	0.0	0.2
7/04/2008	8.0	29.0	18.5	0.0	0.0	0.0	0.0	0.2
8/04/2008	12.0	30.0	21.0	0.0	0.0	0.0	0.0	0.2
9/04/2008	15.0	28.0	21.5	0.0	0.0	0.0	0.0	0.2
10/04/2008	15.0	30.5	22.8	0.0	0.0	0.0	0.0	0.2
11/04/2008	18.0	29.5	23.8	0.0	0.0	0.0	0.0	0.2
12/04/2008	12.0	23.0	17.5	0.0	0.0	0.0	0.0	0.2
13/04/2008	8.0	21.0	14.5	14.5	8.0	0.2	0.2	0.4
14/04/2008	12.0	22.5	17.3	0.0	0.0	0.0	0.0	0.4
15/04/2008	9.0	25.0	17.0	0.0	0.0	0.0	0.0	0.4
16/04/2008	9.0	25.5	17.3	0.0	0.0	0.0	0.0	0.4
17/04/2008	7.0	26.5	16.8	0.0	0.0	0.0	0.0	0.4
18/04/2008	9.0	28.0	18.5	0.0	0.0	0.0	0.0	0.4
19/04/2008	11.0	28.0	19.5	0.0	0.0	0.0	0.0	0.4
20/04/2008	13.0	28.0	20.5	0.0	0.0	0.0	0.0	0.4
21/04/2008	12.0	26.5	19.3	0.0	0.0	0.0	0.0	0.4
22/04/2008	12.0	26.0	19.0	0.0	0.0	0.0	0.0	0.4
23/04/2008	14.0	28.0	21.0	0.0	0.0	0.0	0.0	0.4
24/04/2008	11.0	27.0	19.0	0.0	0.0	0.0	0.0	0.4
25/04/2008	10.0	29.0	19.5	0.0	0.0	0.0	0.0	0.4
26/04/2008	11.0	22.5	16.8	0.0	0.0	0.0	0.0	0.4
27/04/2008	8.0	13.0	10.5	10.5	4.0	3.3	3.3	3.7
28/04/2008	5.0	17.0	11.0	11.0	4.5	2.9	2.9	6.7
29/04/2008	3.0	18.5	10.8	10.8	4.3	3.1	3.1	9.8
30/04/2008	6.0	18.7	12.4	12.4	5.9	1.9	1.9	11.7
1/05/2008	9.0	20.0	14.5	14.5	8.0	0.2	0.2	11.9
2/05/2008	13.0	20.5	16.8	0.0	0.0	0.0	0.0	11.9
3/05/2008	8.5	20.0	14.3	14.3	7.8	0.4	0.4	12.3
4/05/2008	8.0	23.0	15.5	15.5	9.0	-0.6	0.4	12.7
5/05/2008	10.0	24.0	17.0	0.0	0.0	0.0	0.0	12.7
6/05/2008	10.0	21.5	15.8	15.8	9.3	-0.8	0.2	12.9
7/05/2008	11.0	20.0	15.5	15.5	9.0	-0.6	0.4	13.3
8/05/2008	6.0	21.0	13.5	13.5	7.0	1.0	1.0	14.2
9/05/2008	10.0	22.5	16.3	0.0	0.0	0.0	0.0	14.2
10/05/2008	5.0	20.5	12.8	12.8	6.3	1.6	1.6	15.8
11/05/2008	12.5	23.0	17.8	0.0	0.0	0.0	0.0	15.8
12/05/2008	7.0	23.5	15.3	15.3	8.8	-0.4	0.6	16.4
13/05/2008	8.0	24.5	16.3	0.0	0.0	0.0	0.0	16.4
14/05/2008	8.0	25.0	16.5	0.0	0.0	0.0	0.0	16.4
15/05/2008	12.0	21.5	16.8	0.0	0.0	0.0	0.0	16.4
16/05/2008	8.0	21.0	14.5	14.5	8.0	0.2	0.2	16.6
17/05/2008	6.0	16.0	11.0	11.0	4.5	2.9	2.9	19.5
18/05/2008	8.0	17.5	12.8	12.8	6.3	1.6	1.6	21.1
19/05/2008	6.0	18.0	12.0	12.0	5.5	2.2	2.2	23.2
20/05/2008	7.0	19.5	13.3	13.3	6.8	1.2	1.2	24.4
21/05/2008	7.0	21.0	14.0	14.0	7.5	0.6	0.6	25.0
22/05/2008	5.0	18.5	11.8	11.8	5.3	2.4	2.4	27.3
23/05/2008	3.0	21.0	12.0	12.0	5.5	2.2	2.2	29.5
24/05/2008	8.0	23.0	15.5	15.5	9.0	-0.6	0.4	29.9
25/05/2008	10.0	25.0	17.5	0.0	0.0	0.0	0.0	29.9
26/05/2008	8.0	22.0	15.0	15.0	8.5	-0.2	0.8	30.7
27/05/2008	9.0	19.5	14.3	14.3	7.8	0.4	0.4	31.1
28/05/2008	5.0	19.0	12.0	12.0	5.5	2.2	2.2	33.2

BC0805 Planting 1 – Parilla, SA

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
19/11/2008	13.5	25.3	19.4	0.0	0.0	0.0	0.0	0.0
20/11/2008	10.9	21.4	16.1	0.0	0.0	0.0	0.0	0.0
21/11/2008	7.5	21.1	14.3	14.3	7.8	0.3	0.3	0.3
22/11/2008	4.4	16.9	10.6	10.6	4.1	3.2	3.2	3.6
23/11/2008	4.1	23.5	13.8	13.8	7.3	0.7	0.7	4.3
24/11/2008	9.1	27.3	18.2	0.0	0.0	0.0	0.0	4.3
25/11/2008	11.1	30.9	21.0	0.0	0.0	0.0	0.0	4.3
26/11/2008	15.1	34.3	24.7	0.0	0.0	0.0	0.0	4.3
27/11/2008	10.0	29.5	19.8	0.0	0.0	0.0	0.0	4.3
28/11/2008	12.8	18.1	15.5	15.5	9.0	-0.6	0.4	4.7
29/11/2008	9.5	21.3	15.4	15.4	8.9	-0.5	0.5	5.2
30/11/2008	5.9	27.9	16.9	0.0	0.0	0.0	0.0	5.2
1/12/2008	8.8	23.2	16.0	0.0	0.0	0.0	0.0	5.2
2/12/2008	7.9	24.6	16.3	0.0	0.0	0.0	0.0	5.2
3/12/2008	8.6	25.6	17.1	0.0	0.0	0.0	0.0	5.2
4/12/2008	11.5	26.5	19.0	0.0	0.0	0.0	0.0	5.2
5/12/2008	16.1	29.4	22.8	0.0	0.0	0.0	0.0	5.2
6/12/2008	10.1	23.5	16.8	0.0	0.0	0.0	0.0	5.2
7/12/2008	10.3	23.1	16.7	0.0	0.0	0.0	0.0	5.2
8/12/2008	4.4	29.1	16.8	0.0	0.0	0.0	0.0	5.2
9/12/2008	12.3	21.2	16.8	0.0	0.0	0.0	0.0	5.2
10/12/2008	9.7	26.8	18.2	0.0	0.0	0.0	0.0	5.2
11/12/2008	12.6	28.4	20.5	0.0	0.0	0.0	0.0	5.2
12/12/2008	16.7	21.1	18.9	0.0	0.0	0.0	0.0	5.2
13/12/2008	13.4	18.9	16.1	0.0	0.0	0.0	0.0	5.2
14/12/2008	10.3	21.7	16.0	0.0	0.0	0.0	0.0	5.2
15/12/2008	7.6	24.9	16.2	0.0	0.0	0.0	0.0	5.2
16/12/2008	11.5	27.1	19.3	0.0	0.0	0.0	0.0	5.2
17/12/2008	15.7	25.3	20.5	0.0	0.0	0.0	0.0	5.2
18/12/2008	14.6	23.0	18.8	0.0	0.0	0.0	0.0	5.2
19/12/2008	7.3	24.4	15.8	15.8	9.3	-0.9	0.1	5.3
20/12/2008	10.3	28.6	19.5	0.0	0.0	0.0	0.0	5.3
21/12/2008	12.4	34.4	23.4	0.0	0.0	0.0	0.0	5.3
22/12/2008	21.3	28.4	24.8	0.0	0.0	0.0	0.0	5.3
23/12/2008	14.8	27.8	21.3	0.0	0.0	0.0	0.0	5.3
24/12/2008	11.4	32.0	21.7	0.0	0.0	0.0	0.0	5.3
25/12/2008	11.1	29.8	20.4	0.0	0.0	0.0	0.0	5.3
26/12/2008	18.8	36.7	27.8	0.0	0.0	0.0	0.0	5.3
27/12/2008	17.0	28.5	22.8	0.0	0.0	0.0	0.0	5.3
28/12/2008	12.1	27.0	19.6	0.0	0.0	0.0	0.0	5.3
29/12/2008	10.6	24.0	17.3	0.0	0.0	0.0	0.0	5.3
30/12/2008	12.9	24.7	18.8	0.0	0.0	0.0	0.0	5.3
31/12/2008	11.2	25.5	18.3	0.0	0.0	0.0	0.0	5.3
1/01/2009	12.2	23.9	18.0	0.0	0.0	0.0	0.0	5.3
2/01/2009	6.0	24.4	15.2	15.2	8.7	-0.4	0.6	6.0
3/01/2009	9.5	29.1	19.3	0.0	0.0	0.0	0.0	6.0
4/01/2009	11.9	34.3	23.1	0.0	0.0	0.0	0.0	6.0
5/01/2009	9.7	32.7	21.2	0.0	0.0	0.0	0.0	6.0
6/01/2009	10.6	34.7	22.7	0.0	0.0	0.0	0.0	6.0
7/01/2009	13.8	25.5	19.7	0.0	0.0	0.0	0.0	6.0
8/01/2009	8.9	26.2	17.6	0.0	0.0	0.0	0.0	6.0
9/01/2009	9.1	26.0	17.6	0.0	0.0	0.0	0.0	6.0
10/01/2009	8.5	29.8	19.1	0.0	0.0	0.0	0.0	6.0
11/01/2009	10.9	30.0	20.4	0.0	0.0	0.0	0.0	6.0
12/01/2009	9.2	33.5	21.3	0.0	0.0	0.0	0.0	6.0
13/01/2009	15.2	42.3	28.7	0.0	0.0	0.0	0.0	6.0

BC0805 Planting 2 – Parilla, SA

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
10/12/2008	9.7	26.8	18.2	0.0	0.0	0.0	0.0	0.0
11/12/2008	12.6	28.4	20.5	0.0	0.0	0.0	0.0	0.0
12/12/2008	16.7	21.1	18.9	0.0	0.0	0.0	0.0	0.0
13/12/2008	13.4	18.9	16.1	0.0	0.0	0.0	0.0	0.0
14/12/2008	10.3	21.7	16.0	0.0	0.0	0.0	0.0	0.0
15/12/2008	7.6	24.9	16.2	0.0	0.0	0.0	0.0	0.0
16/12/2008	11.5	27.1	19.3	0.0	0.0	0.0	0.0	0.0
17/12/2008	15.7	25.3	20.5	0.0	0.0	0.0	0.0	0.0
18/12/2008	14.6	23.0	18.8	0.0	0.0	0.0	0.0	0.0
19/12/2008	7.3	24.4	15.8	15.8	9.3	-0.9	0.1	0.1
20/12/2008	10.3	28.6	19.5	0.0	0.0	0.0	0.0	0.1
21/12/2008	12.4	34.4	23.4	0.0	0.0	0.0	0.0	0.1
22/12/2008	21.3	28.4	24.8	0.0	0.0	0.0	0.0	0.1
23/12/2008	14.8	27.8	21.3	0.0	0.0	0.0	0.0	0.1
24/12/2008	11.4	32.0	21.7	0.0	0.0	0.0	0.0	0.1
25/12/2008	11.1	29.8	20.4	0.0	0.0	0.0	0.0	0.1
26/12/2008	18.8	36.7	27.8	0.0	0.0	0.0	0.0	0.1
27/12/2008	17.0	28.5	22.8	0.0	0.0	0.0	0.0	0.1
28/12/2008	12.1	27.0	19.6	0.0	0.0	0.0	0.0	0.1
29/12/2008	10.6	24.0	17.3	0.0	0.0	0.0	0.0	0.1
30/12/2008	12.9	24.7	18.8	0.0	0.0	0.0	0.0	0.1
31/12/2008	11.2	25.5	18.3	0.0	0.0	0.0	0.0	0.1
1/01/2009	12.2	23.9	18.0	0.0	0.0	0.0	0.0	0.1
2/01/2009	6.0	24.4	15.2	15.2	8.7	-0.4	0.6	0.8
3/01/2009	9.5	29.1	19.3	0.0	0.0	0.0	0.0	0.8
4/01/2009	11.9	34.3	23.1	0.0	0.0	0.0	0.0	0.8
5/01/2009	9.7	32.7	21.2	0.0	0.0	0.0	0.0	0.8
6/01/2009	10.6	34.7	22.7	0.0	0.0	0.0	0.0	0.8
7/01/2009	13.8	25.5	19.7	0.0	0.0	0.0	0.0	0.8
8/01/2009	8.9	26.2	17.6	0.0	0.0	0.0	0.0	0.8
9/01/2009	9.1	26.0	17.6	0.0	0.0	0.0	0.0	0.8
10/01/2009	8.5	29.8	19.1	0.0	0.0	0.0	0.0	0.8
11/01/2009	10.9	30.0	20.4	0.0	0.0	0.0	0.0	0.8
12/01/2009	9.2	33.5	21.3	0.0	0.0	0.0	0.0	0.8
13/01/2009	15.2	42.3	28.7	0.0	0.0	0.0	0.0	0.8
14/01/2009	17.4	35.3	26.3	0.0	0.0	0.0	0.0	0.8
15/01/2009	12.8	27.7	20.3	0.0	0.0	0.0	0.0	0.8
16/01/2009	9.1	26.4	17.8	0.0	0.0	0.0	0.0	0.8
17/01/2009	7.6	28.7	18.2	0.0	0.0	0.0	0.0	0.8
18/01/2009	11.8	34.1	22.9	0.0	0.0	0.0	0.0	0.8
19/01/2009	15.0	39.4	27.2	0.0	0.0	0.0	0.0	0.8
20/01/2009	13.4	37.7	25.6	0.0	0.0	0.0	0.0	0.8
21/01/2009	11.8	33.3	22.5	0.0	0.0	0.0	0.0	0.8
22/01/2009	15.6	33.3	24.4	0.0	0.0	0.0	0.0	0.8
23/01/2009	8.8	32.4	20.6	0.0	0.0	0.0	0.0	0.8
24/01/2009	14.8	27.3	21.0	0.0	0.0	0.0	0.0	0.8
25/01/2009	8.5	32.6	20.5	0.0	0.0	0.0	0.0	0.8
26/01/2009	11.2	36.6	23.9	0.0	0.0	0.0	0.0	0.8
27/01/2009	18.5	42.6	30.5	0.0	0.0	0.0	0.0	0.8
28/01/2009	20.4	45.5	32.9	0.0	0.0	0.0	0.0	0.8
29/01/2009	26.1	44.8	35.4	0.0	0.0	0.0	0.0	0.8
30/01/2009	24.5	44.9	34.7	0.0	0.0	0.0	0.0	0.8
31/01/2009	22.7	44.2	33.5	0.0	0.0	0.0	0.0	0.8
1/02/2009	24.2	40.2	32.2	0.0	0.0	0.0	0.0	0.8
2/02/2009	24.2	40.6	32.4	0.0	0.0	0.0	0.0	0.8
3/02/2009	18.2	37.6	27.9	0.0	0.0	0.0	0.0	0.8

BC0805 Planting 3 – Parilla, SA

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
1/01/2009	12.2	23.9	18.0	0.0	0.0	0.0	0.0	0.0
2/01/2009	6.0	24.4	15.2	15.2	8.7	-0.4	0.6	0.6
3/01/2009	9.5	29.1	19.3	0.0	0.0	0.0	0.0	0.6
4/01/2009	11.9	34.3	23.1	0.0	0.0	0.0	0.0	0.6
5/01/2009	9.7	32.7	21.2	0.0	0.0	0.0	0.0	0.6
6/01/2009	10.6	34.7	22.7	0.0	0.0	0.0	0.0	0.6
7/01/2009	13.8	25.5	19.7	0.0	0.0	0.0	0.0	0.6
8/01/2009	8.9	26.2	17.6	0.0	0.0	0.0	0.0	0.6
9/01/2009	9.1	26.0	17.6	0.0	0.0	0.0	0.0	0.6
10/01/2009	8.5	29.8	19.1	0.0	0.0	0.0	0.0	0.6
11/01/2009	10.9	30.0	20.4	0.0	0.0	0.0	0.0	0.6
12/01/2009	9.2	33.5	21.3	0.0	0.0	0.0	0.0	0.6
13/01/2009	15.2	42.3	28.7	0.0	0.0	0.0	0.0	0.6
14/01/2009	17.4	35.3	26.3	0.0	0.0	0.0	0.0	0.6
15/01/2009	12.8	27.7	20.3	0.0	0.0	0.0	0.0	0.6
16/01/2009	9.1	26.4	17.8	0.0	0.0	0.0	0.0	0.6
17/01/2009	7.6	28.7	18.2	0.0	0.0	0.0	0.0	0.6
18/01/2009	11.8	34.1	22.9	0.0	0.0	0.0	0.0	0.6
19/01/2009	15.0	39.4	27.2	0.0	0.0	0.0	0.0	0.6
20/01/2009	13.4	37.7	25.6	0.0	0.0	0.0	0.0	0.6
21/01/2009	11.8	33.3	22.5	0.0	0.0	0.0	0.0	0.6
22/01/2009	15.6	33.3	24.4	0.0	0.0	0.0	0.0	0.6
23/01/2009	8.8	32.4	20.6	0.0	0.0	0.0	0.0	0.6
24/01/2009	14.8	27.3	21.0	0.0	0.0	0.0	0.0	0.6
25/01/2009	8.5	32.6	20.5	0.0	0.0	0.0	0.0	0.6
26/01/2009	11.2	36.6	23.9	0.0	0.0	0.0	0.0	0.6
27/01/2009	18.5	42.6	30.5	0.0	0.0	0.0	0.0	0.6
28/01/2009	20.4	45.5	32.9	0.0	0.0	0.0	0.0	0.6
29/01/2009	26.1	44.8	35.4	0.0	0.0	0.0	0.0	0.6
30/01/2009	24.5	44.9	34.7	0.0	0.0	0.0	0.0	0.6
31/01/2009	22.7	44.2	33.5	0.0	0.0	0.0	0.0	0.6
1/02/2009	24.2	40.2	32.2	0.0	0.0	0.0	0.0	0.6
2/02/2009	24.2	40.6	32.4	0.0	0.0	0.0	0.0	0.6
3/02/2009	18.2	37.6	27.9	0.0	0.0	0.0	0.0	0.6
4/02/2009	17.2	38.4	27.8	0.0	0.0	0.0	0.0	0.6
5/02/2009	16.0	36.1	26.0	0.0	0.0	0.0	0.0	0.6
6/02/2009	15.3	42.9	29.1	0.0	0.0	0.0	0.0	0.6
7/02/2009	22.3	47.6	34.9	0.0	0.0	0.0	0.0	0.6
8/02/2009	17.2	26.7	22.0	0.0	0.0	0.0	0.0	0.6
9/02/2009	9.1	24.9	17.0	0.0	0.0	0.0	0.0	0.6
10/02/2009	7.3	22.7	15.0	15.0	8.5	-0.2	0.8	1.4
11/02/2009	7.0	23.5	15.3	15.3	8.8	-0.4	0.6	2.0
12/02/2009	8.2	26.6	17.4	0.0	0.0	0.0	0.0	2.0
13/02/2009	11.9	29.1	20.5	0.0	0.0	0.0	0.0	2.0
14/02/2009	13.8	32.0	22.9	0.0	0.0	0.0	0.0	2.0
15/02/2009	14.3	31.1	22.7	0.0	0.0	0.0	0.0	2.0
16/02/2009	14.6	32.6	23.6	0.0	0.0	0.0	0.0	2.0
17/02/2009	17.2	34.1	25.6	0.0	0.0	0.0	0.0	2.0
18/02/2009	16.0	34.3	25.1	0.0	0.0	0.0	0.0	2.0
19/02/2009	16.4	36.8	26.6	0.0	0.0	0.0	0.0	2.0
20/02/2009	13.0	26.0	19.5	0.0	0.0	0.0	0.0	2.0
21/02/2009	14.2	27.9	21.0	0.0	0.0	0.0	0.0	2.0
22/02/2009	9.9	30.3	20.1	0.0	0.0	0.0	0.0	2.0
23/02/2009	13.0	32.9	23.0	0.0	0.0	0.0	0.0	2.0
24/02/2009	7.0	27.3	17.1	0.0	0.0	0.0	0.0	2.0
25/02/2009	9.9	31.1	20.5	0.0	0.0	0.0	0.0	2.0

BC0805 Planting 4 – Parilla, SA

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
27/01/2009	18.5	42.6	30.5	0.0	0.0	0.0	0.0	0.0
28/01/2009	20.4	45.5	32.9	0.0	0.0	0.0	0.0	0.0
29/01/2009	26.1	44.8	35.4	0.0	0.0	0.0	0.0	0.0
30/01/2009	24.5	44.9	34.7	0.0	0.0	0.0	0.0	0.0
31/01/2009	22.7	44.2	33.5	0.0	0.0	0.0	0.0	0.0
1/02/2009	24.2	40.2	32.2	0.0	0.0	0.0	0.0	0.0
2/02/2009	24.2	40.6	32.4	0.0	0.0	0.0	0.0	0.0
3/02/2009	18.2	37.6	27.9	0.0	0.0	0.0	0.0	0.0
4/02/2009	17.2	38.4	27.8	0.0	0.0	0.0	0.0	0.0
5/02/2009	16.0	36.1	26.0	0.0	0.0	0.0	0.0	0.0
6/02/2009	15.3	42.9	29.1	0.0	0.0	0.0	0.0	0.0
7/02/2009	22.3	47.6	34.9	0.0	0.0	0.0	0.0	0.0
8/02/2009	17.2	26.7	22.0	0.0	0.0	0.0	0.0	0.0
9/02/2009	9.1	24.9	17.0	0.0	0.0	0.0	0.0	0.0
10/02/2009	7.3	22.7	15.0	15.0	8.5	-0.2	0.8	0.8
11/02/2009	7.0	23.5	15.3	15.3	8.8	-0.4	0.6	1.4
12/02/2009	8.2	26.6	17.4	0.0	0.0	0.0	0.0	1.4
13/02/2009	11.9	29.1	20.5	0.0	0.0	0.0	0.0	1.4
14/02/2009	13.8	32.0	22.9	0.0	0.0	0.0	0.0	1.4
15/02/2009	14.3	31.1	22.7	0.0	0.0	0.0	0.0	1.4
16/02/2009	14.6	32.6	23.6	0.0	0.0	0.0	0.0	1.4
17/02/2009	17.2	34.1	25.6	0.0	0.0	0.0	0.0	1.4
18/02/2009	16.0	34.3	25.1	0.0	0.0	0.0	0.0	1.4
19/02/2009	16.4	36.8	26.6	0.0	0.0	0.0	0.0	1.4
20/02/2009	13.0	26.0	19.5	0.0	0.0	0.0	0.0	1.4
21/02/2009	14.2	27.9	21.0	0.0	0.0	0.0	0.0	1.4
22/02/2009	9.9	30.3	20.1	0.0	0.0	0.0	0.0	1.4
23/02/2009	13.0	32.9	23.0	0.0	0.0	0.0	0.0	1.4
24/02/2009	7.0	27.3	17.1	0.0	0.0	0.0	0.0	1.4
25/02/2009	9.9	31.1	20.5	0.0	0.0	0.0	0.0	1.4
26/02/2009	13.0	34.1	23.5	0.0	0.0	0.0	0.0	1.4
27/02/2009	16.4	38.2	27.3	0.0	0.0	0.0	0.0	1.4
28/02/2009	10.9	28.3	19.6	0.0	0.0	0.0	0.0	1.4
1/03/2009	8.7	24.8	16.7	0.0	0.0	0.0	0.0	1.4
2/03/2009	13.6	26.7	20.2	0.0	0.0	0.0	0.0	1.4
3/03/2009	17.3	30.3	23.8	0.0	0.0	0.0	0.0	1.4
4/03/2009	9.3	21.5	15.4	15.4	8.9	-0.5	0.5	1.9
5/03/2009	11.5	23.8	17.6	0.0	0.0	0.0	0.0	1.9
6/03/2009	9.0	23.2	16.1	0.0	0.0	0.0	0.0	1.9
7/03/2009	9.8	24.5	17.2	0.0	0.0	0.0	0.0	1.9
8/03/2009	10.4	27.4	18.9	0.0	0.0	0.0	0.0	1.9
9/03/2009	10.0	29.2	19.6	0.0	0.0	0.0	0.0	1.9
10/03/2009	12.1	27.2	19.7	0.0	0.0	0.0	0.0	1.9
11/03/2009	15.4	29.7	22.6	0.0	0.0	0.0	0.0	1.9
12/03/2009	14.0	32.1	23.0	0.0	0.0	0.0	0.0	1.9
13/03/2009	13.1	32.4	22.8	0.0	0.0	0.0	0.0	1.9
14/03/2009	15.0	24.2	19.6	0.0	0.0	0.0	0.0	1.9
15/03/2009	8.0	20.1	14.1	14.1	7.6	0.5	0.5	2.4
16/03/2009	11.8	21.6	16.7	0.0	0.0	0.0	0.0	2.4
17/03/2009	12.7	24.8	18.7	0.0	0.0	0.0	0.0	2.4
18/03/2009	8.3	29.6	19.0	0.0	0.0	0.0	0.0	2.4
19/03/2009	13.4	31.8	22.6	0.0	0.0	0.0	0.0	2.4
20/03/2009	8.4	30.9	19.6	0.0	0.0	0.0	0.0	2.4
21/03/2009	13.3	37.2	25.3	0.0	0.0	0.0	0.0	2.4
22/03/2009	14.4	24.4	19.4	0.0	0.0	0.0	0.0	2.4
23/03/2009	6.5	24.4	15.4	15.4	8.9	-0.6	0.4	2.8

BC0805 Planting 5 – Parilla, SA

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
18/02/2009	15.0	36.2	25.6	0.0	0.0	0.0	0.0	0.0
19/02/2009	18.4	38.4	28.4	0.0	0.0	0.0	0.0	0.0
20/02/2009	18.8	25.3	22.0	0.0	0.0	0.0	0.0	0.0
21/02/2009	11.2	28.2	19.7	0.0	0.0	0.0	0.0	0.0
22/02/2009	15.0	25.1	20.1	0.0	0.0	0.0	0.0	0.0
23/02/2009	9.6	23.0	16.3	0.0	0.0	0.0	0.0	0.0
24/02/2009	11.9	24.3	18.1	0.0	0.0	0.0	0.0	0.0
25/02/2009	8.9	25.2	17.1	0.0	0.0	0.0	0.0	0.0
26/02/2009	11.2	28.2	19.7	0.0	0.0	0.0	0.0	0.0
27/02/2009	10.8	24.8	17.8	0.0	0.0	0.0	0.0	0.0
28/02/2009	7.7	24.1	15.9	15.9	9.4	-0.9	0.1	0.1
1/03/2009	6.5	24.0	15.3	15.3	8.8	-0.4	0.6	0.7
2/03/2009	7.2	26.0	16.6	0.0	0.0	0.0	0.0	0.7
3/03/2009	9.4	31.2	20.3	0.0	0.0	0.0	0.0	0.7
4/03/2009	12.3	35.0	23.7	0.0	0.0	0.0	0.0	0.7
5/03/2009	17.1	33.7	25.4	0.0	0.0	0.0	0.0	0.7
6/03/2009	15.1	36.4	25.8	0.0	0.0	0.0	0.0	0.7
7/03/2009	17.8	38.7	28.3	0.0	0.0	0.0	0.0	0.7
8/03/2009	15.8	36.3	26.0	0.0	0.0	0.0	0.0	0.7
9/03/2009	16.4	39.5	27.9	0.0	0.0	0.0	0.0	0.7
10/03/2009	19.0	39.3	29.1	0.0	0.0	0.0	0.0	0.7
11/03/2009	20.8	40.6	30.7	0.0	0.0	0.0	0.0	0.7
12/03/2009	16.1	37.7	26.9	0.0	0.0	0.0	0.0	0.7
13/03/2009	16.8	38.8	27.8	0.0	0.0	0.0	0.0	0.7
14/03/2009	19.9	41.7	30.8	0.0	0.0	0.0	0.0	0.7
15/03/2009	22.8	40.3	31.5	0.0	0.0	0.0	0.0	0.7
16/03/2009	16.8	38.7	27.8	0.0	0.0	0.0	0.0	0.7
17/03/2009	19.3	40.7	30.0	0.0	0.0	0.0	0.0	0.7
18/03/2009	20.8	40.5	30.6	0.0	0.0	0.0	0.0	0.7
19/03/2009	18.9	29.7	24.3	0.0	0.0	0.0	0.0	0.7
20/03/2009	8.8	28.0	18.4	0.0	0.0	0.0	0.0	0.7
21/03/2009	9.9	24.8	17.3	0.0	0.0	0.0	0.0	0.7
22/03/2009	5.9	22.4	14.1	14.1	7.6	0.5	0.5	1.1
23/03/2009	6.8	25.4	16.1	0.0	0.0	0.0	0.0	1.1
24/03/2009	7.3	30.2	18.8	0.0	0.0	0.0	0.0	1.1
25/03/2009	15.8	33.2	24.5	0.0	0.0	0.0	0.0	1.1
26/03/2009	10.0	23.6	16.8	0.0	0.0	0.0	0.0	1.1
27/03/2009	10.1	18.4	14.3	14.3	7.8	0.4	0.4	1.5
28/03/2009	3.2	19.4	11.3	11.3	4.8	2.7	2.7	4.2
29/03/2009	3.1	19.8	11.4	11.4	4.9	2.6	2.6	6.8
30/03/2009	7.1	18.9	13.0	13.0	6.5	1.4	1.4	8.2
31/03/2009	4.4	21.7	13.1	13.1	6.6	1.3	1.3	9.5
1/04/2009	7.2	22.6	14.9	14.9	8.4	-0.1	0.9	10.4
2/04/2009	7.2	27.0	17.1	0.0	0.0	0.0	0.0	10.4
3/04/2009	12.4	24.8	18.6	0.0	0.0	0.0	0.0	10.4
4/04/2009	6.4	17.3	11.8	11.8	5.3	2.3	2.3	12.7
5/04/2009	6.5	19.6	13.1	13.1	6.6	1.3	1.3	14.0
6/04/2009	11.2	22.2	16.7	0.0	0.0	0.0	0.0	14.0
7/04/2009	10.3	24.2	17.3	0.0	0.0	0.0	0.0	14.0
8/04/2009	7.9	25.1	16.5	0.0	0.0	0.0	0.0	14.0
9/04/2009	10.0	29.0	19.5	0.0	0.0	0.0	0.0	14.0
10/04/2009	14.5	25.2	19.9	0.0	0.0	0.0	0.0	14.0
11/04/2009	12.9	31.0	21.9	0.0	0.0	0.0	0.0	14.0
12/04/2009	14.4	26.3	20.3	0.0	0.0	0.0	0.0	14.0
13/04/2009	7.4	20.3	13.8	13.8	7.3	0.7	0.7	14.7
14/04/2009	10.1	17.2	13.7	13.7	7.2	0.9	0.9	15.5

BC0806 – Parilla, SA

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
12/02/2008	10.9	28.1	19.5	0.0	0.0	0.0	0.0	0.0
13/02/2008	8.0	26.3	17.1	0.0	0.0	0.0	0.0	0.0
14/02/2008	9.8	30.0	19.9	0.0	0.0	0.0	0.0	0.0
15/02/2008	14.3	33.6	23.9	0.0	0.0	0.0	0.0	0.0
16/02/2008	18.2	36.8	27.5	0.0	0.0	0.0	0.0	0.0
17/02/2008	18.2	36.1	27.1	0.0	0.0	0.0	0.0	0.0
18/02/2008	15.0	36.2	25.6	0.0	0.0	0.0	0.0	0.0
19/02/2008	18.4	38.4	28.4	0.0	0.0	0.0	0.0	0.0
20/02/2008	18.8	25.3	22.0	0.0	0.0	0.0	0.0	0.0
21/02/2008	11.2	28.2	19.7	0.0	0.0	0.0	0.0	0.0
22/02/2008	15.0	25.1	20.1	0.0	0.0	0.0	0.0	0.0
23/02/2008	9.6	23.0	16.3	0.0	0.0	0.0	0.0	0.0
24/02/2008	11.9	24.3	18.1	0.0	0.0	0.0	0.0	0.0
25/02/2008	8.9	25.2	17.1	0.0	0.0	0.0	0.0	0.0
26/02/2008	11.2	28.2	19.7	0.0	0.0	0.0	0.0	0.0
27/02/2008	10.8	24.8	17.8	0.0	0.0	0.0	0.0	0.0
28/02/2008	7.7	24.1	15.9	15.9	9.4	-0.9	0.1	0.1
29/02/2008	6.5	24.0	15.3	15.3	8.8	-0.4	0.6	0.7
1/03/2008	7.2	26.0	16.6	0.0	0.0	0.0	0.0	0.7
2/03/2008	9.4	31.2	20.3	0.0	0.0	0.0	0.0	0.7
3/03/2008	12.3	35.0	23.7	0.0	0.0	0.0	0.0	0.7
4/03/2008	17.1	33.7	25.4	0.0	0.0	0.0	0.0	0.7
5/03/2008	15.1	36.4	25.8	0.0	0.0	0.0	0.0	0.7
6/03/2008	17.8	38.7	28.3	0.0	0.0	0.0	0.0	0.7
7/03/2008	15.8	36.3	26.0	0.0	0.0	0.0	0.0	0.7
8/03/2008	16.4	39.5	27.9	0.0	0.0	0.0	0.0	0.7
9/03/2008	19.0	39.3	29.1	0.0	0.0	0.0	0.0	0.7
10/03/2008	20.8	40.6	30.7	0.0	0.0	0.0	0.0	0.7
11/03/2008	16.1	37.7	26.9	0.0	0.0	0.0	0.0	0.7
12/03/2008	16.8	38.8	27.8	0.0	0.0	0.0	0.0	0.7
13/03/2008	19.9	41.7	30.8	0.0	0.0	0.0	0.0	0.7
14/03/2008	22.8	40.3	31.5	0.0	0.0	0.0	0.0	0.7
15/03/2008	16.8	38.7	27.8	0.0	0.0	0.0	0.0	0.7
16/03/2008	19.3	40.7	30.0	0.0	0.0	0.0	0.0	0.7
17/03/2008	20.8	40.5	30.6	0.0	0.0	0.0	0.0	0.7
18/03/2008	18.9	29.7	24.3	0.0	0.0	0.0	0.0	0.7
19/03/2008	8.8	28.0	18.4	0.0	0.0	0.0	0.0	0.7
20/03/2008	9.9	24.8	17.3	0.0	0.0	0.0	0.0	0.7
21/03/2008	5.9	22.4	14.1	14.1	7.6	0.5	0.5	1.1
22/03/2008	6.8	25.4	16.1	0.0	0.0	0.0	0.0	1.1
23/03/2008	7.3	30.2	18.8	0.0	0.0	0.0	0.0	1.1
24/03/2008	15.8	33.2	24.5	0.0	0.0	0.0	0.0	1.1
25/03/2008	10.0	23.6	16.8	0.0	0.0	0.0	0.0	1.1
26/03/2008	10.1	18.4	14.3	14.3	7.8	0.4	0.4	1.5
27/03/2008	3.2	19.4	11.3	11.3	4.8	2.7	2.7	4.2
28/03/2008	3.1	19.8	11.4	11.4	4.9	2.6	2.6	6.8
29/03/2008	7.1	18.9	13.0	13.0	6.5	1.4	1.4	8.2
30/03/2008	4.4	21.7	13.1	13.1	6.6	1.3	1.3	9.5
31/03/2008	7.2	22.6	14.9	14.9	8.4	-0.1	0.9	10.4
1/04/2008	7.2	27.0	17.1	0.0	0.0	0.0	0.0	10.4
2/04/2008	12.4	24.8	18.6	0.0	0.0	0.0	0.0	10.4
3/04/2008	6.4	17.3	11.8	11.8	5.3	2.3	2.3	12.7
4/04/2008	6.5	19.6	13.1	13.1	6.6	1.3	1.3	14.0
5/04/2008	11.2	22.2	16.7	0.0	0.0	0.0	0.0	14.0
6/04/2008	10.3	24.2	17.3	0.0	0.0	0.0	0.0	14.0
7/04/2008	7.9	25.1	16.5	0.0	0.0	0.0	0.0	14.0

BC0901 – Clyde, Vic

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
3/02/2009	18.8	28.0	23.4	0.0	0.0	0.0	0.0	0.0
4/02/2009	18.0	32.5	25.3	0.0	0.0	0.0	0.0	0.0
5/02/2009	17.0	29.5	23.3	0.0	0.0	0.0	0.0	0.0
6/02/2009	15.5	39.5	27.5	0.0	0.0	0.0	0.0	0.0
7/02/2009	16.0	46.0	31.0	0.0	0.0	0.0	0.0	0.0
8/02/2009	15.5	20.5	18.0	0.0	0.0	0.0	0.0	0.0
9/02/2009	12.5	20.0	16.3	0.0	0.0	0.0	0.0	0.0
10/02/2009	10.0	19.0	14.5	14.5	8.0	0.2	0.2	0.2
11/02/2009	12.0	18.8	15.4	15.4	8.9	-0.5	0.5	0.7
12/02/2009	10.6	20.4	15.5	15.5	9.0	-0.6	0.4	1.1
13/02/2009	10.2	24.5	17.3	0.0	0.0	0.0	0.0	1.1
14/02/2009	8.0	27.4	17.7	0.0	0.0	0.0	0.0	1.1
15/02/2009	15.6	28.0	21.8	0.0	0.0	0.0	0.0	1.1
16/02/2009	15.5	27.7	21.6	0.0	0.0	0.0	0.0	1.1
17/02/2009	13.8	28.9	21.3	0.0	0.0	0.0	0.0	1.1
18/02/2009	12.1	29.3	20.7	0.0	0.0	0.0	0.0	1.1
19/02/2009	12.5	29.0	20.8	0.0	0.0	0.0	0.0	1.1
20/02/2009	15.0	23.0	19.0	0.0	0.0	0.0	0.0	1.1
21/02/2009	15.3	21.0	18.2	0.0	0.0	0.0	0.0	1.1
22/02/2009	15.0	24.5	19.8	0.0	0.0	0.0	0.0	1.1
23/02/2009	13.5	33.5	23.5	0.0	0.0	0.0	0.0	1.1
24/02/2009	10.5	20.3	15.4	15.4	8.9	-0.5	0.5	1.5
25/02/2009	11.9	19.5	15.7	15.7	9.2	-0.8	0.2	1.8
26/02/2009	11.0	29.3	20.1	0.0	0.0	0.0	0.0	1.8
27/02/2009	14.5	34.0	24.3	0.0	0.0	0.0	0.0	1.8
28/02/2009	15.5	20.4	17.9	0.0	0.0	0.0	0.0	1.8
1/03/2009	13.1	21.0	17.1	0.0	0.0	0.0	0.0	1.8
2/03/2009	13.0	26.4	19.7	0.0	0.0	0.0	0.0	1.8
3/03/2009	15.4	32.2	23.8	0.0	0.0	0.0	0.0	1.8
4/03/2009	13.2	19.5	16.3	0.0	0.0	0.0	0.0	1.8
5/03/2009	11.5	16.9	14.2	14.2	7.7	0.4	0.4	2.2
6/03/2009	11.5	18.9	15.2	15.2	8.7	-0.4	0.6	2.8
7/03/2009	12.2	20.0	16.1	0.0	0.0	0.0	0.0	2.8
8/03/2009	10.8	20.0	15.4	15.4	8.9	-0.5	0.5	3.3
9/03/2009	8.8	25.5	17.2	0.0	0.0	0.0	0.0	3.3
10/03/2009	13.5	27.5	20.5	0.0	0.0	0.0	0.0	3.3
11/03/2009	15.0	29.0	22.0	0.0	0.0	0.0	0.0	3.3
12/03/2009	16.2	26.3	21.3	0.0	0.0	0.0	0.0	3.3
13/03/2009	14.3	28.5	21.4	0.0	0.0	0.0	0.0	3.3
14/03/2009	16.0	24.5	20.3	0.0	0.0	0.0	0.0	3.3
15/03/2009	10.5	17.5	14.0	14.0	7.5	0.6	0.6	3.9
16/03/2009	11.4	19.8	15.6	15.6	9.1	-0.7	0.3	4.2
17/03/2009	12.2	17.5	14.8	14.8	8.3	-0.1	0.9	5.1
18/03/2009	10.0	26.0	18.0	0.0	0.0	0.0	0.0	5.1
19/03/2009	10.2	31.5	20.8	0.0	0.0	0.0	0.0	5.1
20/03/2009	14.0	23.5	18.8	0.0	0.0	0.0	0.0	5.1
21/03/2009	12.4	34.5	23.4	0.0	0.0	0.0	0.0	5.1
22/03/2009	20.0	25.1	22.6	0.0	0.0	0.0	0.0	5.1
23/03/2009	12.6	18.5	15.6	15.6	9.1	-0.6	0.4	5.4
24/03/2009	11.0	20.3	15.6	15.6	9.1	-0.7	0.3	5.7
25/03/2009	14.7	23.2	19.0	0.0	0.0	0.0	0.0	5.7
26/03/2009	14.0	22.0	18.0	0.0	0.0	0.0	0.0	5.7
27/03/2009	10.5	20.5	15.5	15.5	9.0	-0.6	0.4	6.1
28/03/2009	8.5	26.2	17.4	0.0	0.0	0.0	0.0	6.1
29/03/2009	9.8	25.0	17.4	0.0	0.0	0.0	0.0	6.1
30/03/2009	11.4	23.0	17.2	0.0	0.0	0.0	0.0	6.1

BC0902 – Dareton, NSW

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
26/01/2009	19.0	41.0	30.0	0.0	0.0	0.0	0.0	0.0
27/01/2009	21.0	44.4	32.7	0.0	0.0	0.0	0.0	0.0
28/01/2009	29.0	45.0	37.0	0.0	0.0	0.0	0.0	0.0
29/01/2009	29.0	44.0	36.5	0.0	0.0	0.0	0.0	0.0
30/01/2009	28.0	45.0	36.5	0.0	0.0	0.0	0.0	0.0
31/01/2009	29.0	45.5	37.3	0.0	0.0	0.0	0.0	0.0
1/02/2009	27.0	45.0	36.0	0.0	0.0	0.0	0.0	0.0
2/02/2009	27.0	45.5	36.3	0.0	0.0	0.0	0.0	0.0
3/02/2009	26.0	42.5	34.3	0.0	0.0	0.0	0.0	0.0
4/02/2009	23.0	42.0	32.5	0.0	0.0	0.0	0.0	0.0
5/02/2009	22.0	43.0	32.5	0.0	0.0	0.0	0.0	0.0
6/02/2009	23.0	45.0	34.0	0.0	0.0	0.0	0.0	0.0
7/02/2009	29.0	48.0	38.5	0.0	0.0	0.0	0.0	0.0
8/02/2009	22.0	35.0	28.5	0.0	0.0	0.0	0.0	0.0
9/02/2009	15.0	28.5	21.8	0.0	0.0	0.0	0.0	0.0
10/02/2009	12.0	26.0	19.0	0.0	0.0	0.0	0.0	0.0
11/02/2009	10.0	26.0	18.0	0.0	0.0	0.0	0.0	0.0
12/02/2009	10.0	28.0	19.0	0.0	0.0	0.0	0.0	0.0
13/02/2009	11.0	30.0	20.5	0.0	0.0	0.0	0.0	0.0
14/02/2009	15.0	33.0	24.0	0.0	0.0	0.0	0.0	0.0
15/02/2009	18.0	34.0	26.0	0.0	0.0	0.0	0.0	0.0
16/02/2009	20.0	34.0	27.0	0.0	0.0	0.0	0.0	0.0
17/02/2009	19.0	36.0	27.5	0.0	0.0	0.0	0.0	0.0
18/02/2009	23.0	36.0	29.5	0.0	0.0	0.0	0.0	0.0
19/02/2009	22.0	37.0	29.5	0.0	0.0	0.0	0.0	0.0
20/02/2009	20.0	33.0	26.5	0.0	0.0	0.0	0.0	0.0
21/02/2009	17.0	33.0	25.0	0.0	0.0	0.0	0.0	0.0
22/02/2009	15.0	38.0	26.5	0.0	0.0	0.0	0.0	0.0
23/02/2009	12.0	32.0	22.0	0.0	0.0	0.0	0.0	0.0
24/02/2009	12.0	33.0	22.5	0.0	0.0	0.0	0.0	0.0
25/02/2009	16.0	36.0	26.0	0.0	0.0	0.0	0.0	0.0
26/02/2009	20.0	40.5	30.3	0.0	0.0	0.0	0.0	0.0
27/02/2009	15.0	32.0	23.5	0.0	0.0	0.0	0.0	0.0
28/02/2009	16.0	32.0	24.0	0.0	0.0	0.0	0.0	0.0
1/03/2009	16.0	28.0	22.0	0.0	0.0	0.0	0.0	0.0
2/03/2009	16.0	31.0	23.5	0.0	0.0	0.0	0.0	0.0
3/03/2009	23.0	38.5	30.8	0.0	0.0	0.0	0.0	0.0
4/03/2009	12.0	24.0	18.0	0.0	0.0	0.0	0.0	0.0
5/03/2009	14.0	26.0	20.0	0.0	0.0	0.0	0.0	0.0
6/03/2009	10.0	26.5	18.3	0.0	0.0	0.0	0.0	0.0
7/03/2009	13.0	30.0	21.5	0.0	0.0	0.0	0.0	0.0
8/03/2009	14.0	32.0	23.0	0.0	0.0	0.0	0.0	0.0
9/03/2009	14.0	34.0	24.0	0.0	0.0	0.0	0.0	0.0
10/03/2009	19.0	23.0	21.0	0.0	0.0	0.0	0.0	0.0
11/03/2009	18.0	33.0	25.5	0.0	0.0	0.0	0.0	0.0
12/03/2009	20.0	29.0	24.5	0.0	0.0	0.0	0.0	0.0
13/03/2009	18.0	32.0	25.0	0.0	0.0	0.0	0.0	0.0
14/03/2009	21.0	29.0	25.0	0.0	0.0	0.0	0.0	0.0
15/03/2009	10.0	22.5	16.3	0.0	0.0	0.0	0.0	0.0
16/03/2009	13.0	24.0	18.5	0.0	0.0	0.0	0.0	0.0
17/03/2009	10.0	23.0	16.5	0.0	0.0	0.0	0.0	0.0
18/03/2009	11.0	30.0	20.5	0.0	0.0	0.0	0.0	0.0
19/03/2009	14.0	36.0	25.0	0.0	0.0	0.0	0.0	0.0
20/03/2009	15.0	36.0	25.5	0.0	0.0	0.0	0.0	0.0
21/03/2009	19.0	38.0	28.5	0.0	0.0	0.0	0.0	0.0
22/03/2009	23.0	29.0	26.0	0.0	0.0	0.0	0.0	0.0

BC0903 – Dareton, NSW

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
23/01/2009	20.0	34.0	27.0	0.0	0.0	0.0	0.0	0.0
24/01/2009	18.0	32.0	25.0	0.0	0.0	0.0	0.0	0.0
25/01/2009	15.0	37.5	26.3	0.0	0.0	0.0	0.0	0.0
26/01/2009	19.0	41.0	30.0	0.0	0.0	0.0	0.0	0.0
27/01/2009	21.0	44.4	32.7	0.0	0.0	0.0	0.0	0.0
28/01/2009	29.0	45.0	37.0	0.0	0.0	0.0	0.0	0.0
29/01/2009	29.0	44.0	36.5	0.0	0.0	0.0	0.0	0.0
30/01/2009	28.0	45.0	36.5	0.0	0.0	0.0	0.0	0.0
31/01/2009	29.0	45.5	37.3	0.0	0.0	0.0	0.0	0.0
1/02/2009	27.0	45.0	36.0	0.0	0.0	0.0	0.0	0.0
2/02/2009	27.0	45.5	36.3	0.0	0.0	0.0	0.0	0.0
3/02/2009	26.0	42.5	34.3	0.0	0.0	0.0	0.0	0.0
4/02/2009	23.0	42.0	32.5	0.0	0.0	0.0	0.0	0.0
5/02/2009	22.0	43.0	32.5	0.0	0.0	0.0	0.0	0.0
6/02/2009	23.0	45.0	34.0	0.0	0.0	0.0	0.0	0.0
7/02/2009	29.0	48.0	38.5	0.0	0.0	0.0	0.0	0.0
8/02/2009	22.0	35.0	28.5	0.0	0.0	0.0	0.0	0.0
9/02/2009	15.0	28.5	21.8	0.0	0.0	0.0	0.0	0.0
10/02/2009	12.0	26.0	19.0	0.0	0.0	0.0	0.0	0.0
11/02/2009	10.0	26.0	18.0	0.0	0.0	0.0	0.0	0.0
12/02/2009	10.0	28.0	19.0	0.0	0.0	0.0	0.0	0.0
13/02/2009	11.0	30.0	20.5	0.0	0.0	0.0	0.0	0.0
14/02/2009	15.0	33.0	24.0	0.0	0.0	0.0	0.0	0.0
15/02/2009	18.0	34.0	26.0	0.0	0.0	0.0	0.0	0.0
16/02/2009	20.0	34.0	27.0	0.0	0.0	0.0	0.0	0.0
17/02/2009	19.0	36.0	27.5	0.0	0.0	0.0	0.0	0.0
18/02/2009	23.0	36.0	29.5	0.0	0.0	0.0	0.0	0.0
19/02/2009	22.0	37.0	29.5	0.0	0.0	0.0	0.0	0.0
20/02/2009	20.0	33.0	26.5	0.0	0.0	0.0	0.0	0.0
21/02/2009	17.0	33.0	25.0	0.0	0.0	0.0	0.0	0.0
22/02/2009	15.0	38.0	26.5	0.0	0.0	0.0	0.0	0.0
23/02/2009	12.0	32.0	22.0	0.0	0.0	0.0	0.0	0.0
24/02/2009	12.0	33.0	22.5	0.0	0.0	0.0	0.0	0.0
25/02/2009	16.0	36.0	26.0	0.0	0.0	0.0	0.0	0.0
26/02/2009	20.0	40.5	30.3	0.0	0.0	0.0	0.0	0.0
27/02/2009	15.0	32.0	23.5	0.0	0.0	0.0	0.0	0.0
28/02/2009	16.0	32.0	24.0	0.0	0.0	0.0	0.0	0.0
1/03/2009	16.0	28.0	22.0	0.0	0.0	0.0	0.0	0.0
2/03/2009	16.0	31.0	23.5	0.0	0.0	0.0	0.0	0.0
3/03/2009	23.0	38.5	30.8	0.0	0.0	0.0	0.0	0.0
4/03/2009	12.0	24.0	18.0	0.0	0.0	0.0	0.0	0.0
5/03/2009	14.0	26.0	20.0	0.0	0.0	0.0	0.0	0.0
6/03/2009	10.0	26.5	18.3	0.0	0.0	0.0	0.0	0.0
7/03/2009	13.0	30.0	21.5	0.0	0.0	0.0	0.0	0.0
8/03/2009	14.0	32.0	23.0	0.0	0.0	0.0	0.0	0.0
9/03/2009	14.0	34.0	24.0	0.0	0.0	0.0	0.0	0.0
10/03/2009	19.0	23.0	21.0	0.0	0.0	0.0	0.0	0.0
11/03/2009	18.0	33.0	25.5	0.0	0.0	0.0	0.0	0.0
12/03/2009	20.0	29.0	24.5	0.0	0.0	0.0	0.0	0.0
13/03/2009	18.0	32.0	25.0	0.0	0.0	0.0	0.0	0.0
14/03/2009	21.0	29.0	25.0	0.0	0.0	0.0	0.0	0.0
15/03/2009	10.0	22.5	16.3	0.0	0.0	0.0	0.0	0.0
16/03/2009	13.0	24.0	18.5	0.0	0.0	0.0	0.0	0.0
17/03/2009	10.0	23.0	16.5	0.0	0.0	0.0	0.0	0.0
18/03/2009	11.0	30.0	20.5	0.0	0.0	0.0	0.0	0.0
19/03/2009	14.0	36.0	25.0	0.0	0.0	0.0	0.0	0.0

BC0905 – Clyde, Vic

Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
11/02/2009	12.0	18.8	15.4	15.4	8.9	-0.5	0.5	0.5
12/02/2009	10.6	20.4	15.5	15.5	9.0	-0.6	0.4	0.9
13/02/2009	10.2	24.5	17.3	0.0	0.0	0.0	0.0	0.9
14/02/2009	8.0	27.4	17.7	0.0	0.0	0.0	0.0	0.9
15/02/2009	15.6	28.0	21.8	0.0	0.0	0.0	0.0	0.9
16/02/2009	15.5	27.7	21.6	0.0	0.0	0.0	0.0	0.9
17/02/2009	13.8	28.9	21.3	0.0	0.0	0.0	0.0	0.9
18/02/2009	12.1	29.3	20.7	0.0	0.0	0.0	0.0	0.9
19/02/2009	12.5	29.0	20.8	0.0	0.0	0.0	0.0	0.9
20/02/2009	15.0	23.0	19.0	0.0	0.0	0.0	0.0	0.9
21/02/2009	15.3	21.0	18.2	0.0	0.0	0.0	0.0	0.9
22/02/2009	15.0	24.5	19.8	0.0	0.0	0.0	0.0	0.9
23/02/2009	13.5	33.5	23.5	0.0	0.0	0.0	0.0	0.9
24/02/2009	10.5	20.3	15.4	15.4	8.9	-0.5	0.5	1.3
25/02/2009	11.9	19.5	15.7	15.7	9.2	-0.8	0.2	1.6
26/02/2009	11.0	29.3	20.1	0.0	0.0	0.0	0.0	1.6
27/02/2009	14.5	34.0	24.3	0.0	0.0	0.0	0.0	1.6
28/02/2009	15.5	20.4	17.9	0.0	0.0	0.0	0.0	1.6
1/03/2009	13.1	21.0	17.1	0.0	0.0	0.0	0.0	1.6
2/03/2009	13.0	26.4	19.7	0.0	0.0	0.0	0.0	1.6
3/03/2009	15.4	32.2	23.8	0.0	0.0	0.0	0.0	1.6
4/03/2009	13.2	19.5	16.3	0.0	0.0	0.0	0.0	1.6
5/03/2009	11.5	16.9	14.2	14.2	7.7	0.4	0.4	2.0
6/03/2009	11.5	18.9	15.2	15.2	8.7	-0.4	0.6	2.6
7/03/2009	12.2	20.0	16.1	0.0	0.0	0.0	0.0	2.6
8/03/2009	10.8	20.0	15.4	15.4	8.9	-0.5	0.5	3.1
9/03/2009	8.8	25.5	17.2	0.0	0.0	0.0	0.0	3.1
10/03/2009	13.5	27.5	20.5	0.0	0.0	0.0	0.0	3.1
11/03/2009	15.0	29.0	22.0	0.0	0.0	0.0	0.0	3.1
12/03/2009	16.2	26.3	21.3	0.0	0.0	0.0	0.0	3.1
13/03/2009	14.3	28.5	21.4	0.0	0.0	0.0	0.0	3.1
14/03/2009	16.0	24.5	20.3	0.0	0.0	0.0	0.0	3.1
15/03/2009	10.5	17.5	14.0	14.0	7.5	0.6	0.6	3.7
16/03/2009	11.4	19.8	15.6	15.6	9.1	-0.7	0.3	4.0
17/03/2009	12.2	17.5	14.8	14.8	8.3	-0.1	0.9	4.9
18/03/2009	10.0	26.0	18.0	0.0	0.0	0.0	0.0	4.9
19/03/2009	10.2	31.5	20.8	0.0	0.0	0.0	0.0	4.9
20/03/2009	14.0	23.5	18.8	0.0	0.0	0.0	0.0	4.9
21/03/2009	12.4	34.5	23.4	0.0	0.0	0.0	0.0	4.9
22/03/2009	20.0	25.1	22.6	0.0	0.0	0.0	0.0	4.9
23/03/2009	12.6	18.5	15.6	15.6	9.1	-0.6	0.4	5.3
24/03/2009	11.0	20.3	15.6	15.6	9.1	-0.7	0.3	5.5
25/03/2009	14.7	23.2	19.0	0.0	0.0	0.0	0.0	5.5
26/03/2009	14.0	22.0	18.0	0.0	0.0	0.0	0.0	5.5
27/03/2009	10.5	20.5	15.5	15.5	9.0	-0.6	0.4	5.9
28/03/2009	8.5	26.2	17.4	0.0	0.0	0.0	0.0	5.9
29/03/2009	9.8	25.0	17.4	0.0	0.0	0.0	0.0	5.9
30/03/2009	11.4	23.0	17.2	0.0	0.0	0.0	0.0	5.9
31/03/2009	11.0	27.4	19.2	0.0	0.0	0.0	0.0	5.9
1/04/2009	12.2	28.0	20.1	0.0	0.0	0.0	0.0	5.9
2/04/2009	14.0	32.0	23.0	0.0	0.0	0.0	0.0	5.9
3/04/2009	18.0	24.0	21.0	0.0	0.0	0.0	0.0	5.9
4/04/2009	8.5	18.2	13.4	13.4	6.9	1.1	1.1	7.0
5/04/2009	10.9	17.7	14.3	14.3	7.8	0.3	0.3	7.4
6/04/2009	7.7	16.1	11.9	11.9	5.4	2.2	2.2	9.6
7/04/2009	9.9	17.5	13.7	13.7	7.2	0.8	0.8	10.4

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Date	Min. Temp. (°C)	Max. Temp. (°C)	Av. Temp. (°C)	T_{exp} (°C) on Days with <16.0°C Anomaly	6.5-16.0°C Anomaly	T_{eff} (°C)	Daily °Cd	Cumulative °Cd (6.5-16.0)
27/11/2009	16.8	26.4	21.6	0.0	0.0	0.0	0.0	0.0
28/11/2009	14.2	23.0	18.6	0.0	0.0	0.0	0.0	0.0
29/11/2009	11.9	19.3	15.6	15.6	9.1	-0.7	0.3	0.3
30/11/2009	12.6	19.0	15.8	15.8	9.3	-0.8	0.2	0.5
1/12/2009	10.6	17.9	14.3	14.3	7.8	0.4	0.4	0.9
2/12/2009	10.4	26.1	18.2	0.0	0.0	0.0	0.0	0.9
3/12/2009	13.0	30.6	21.8	0.0	0.0	0.0	0.0	0.9
4/12/2009	9.3	19.1	14.2	14.2	7.7	0.4	0.4	1.3
5/12/2009	11.3	20.3	15.8	15.8	9.3	-0.8	0.2	1.5
6/12/2009	9.9	21.5	15.7	15.7	9.2	-0.7	0.3	1.7
7/12/2009	10.9	20.6	15.8	15.8	9.3	-0.8	0.2	1.9
8/12/2009	12.4	16.4	14.4	14.4	7.9	0.3	0.3	2.2
9/12/2009	7.3	23.8	15.6	15.6	9.1	-0.6	0.4	2.5
10/12/2009	10.9	23.3	17.1	0.0	0.0	0.0	0.0	2.5
11/12/2009	10.2	18.7	14.4	14.4	7.9	0.2	0.2	2.8
12/12/2009	11.9	21.4	16.7	0.0	0.0	0.0	0.0	2.8
13/12/2009	14.0	19.4	16.7	0.0	0.0	0.0	0.0	2.8
14/12/2009	9.5	18.6	14.1	14.1	7.6	0.5	0.5	3.3
15/12/2009	7.3	25.8	16.6	0.0	0.0	0.0	0.0	3.3
16/12/2009	13.0	37.5	25.2	0.0	0.0	0.0	0.0	3.3
17/12/2009	15.7	21.0	18.3	0.0	0.0	0.0	0.0	3.3
18/12/2009	9.5	21.5	15.5	15.5	9.0	-0.6	0.4	3.8
19/12/2009	13.5	18.7	16.1	0.0	0.0	0.0	0.0	3.8
20/12/2009	11.1	20.1	15.6	15.6	9.1	-0.7	0.3	4.1
21/12/2009	8.3	23.4	15.9	15.9	9.4	-0.9	0.1	4.2
22/12/2009	12.6	23.0	17.8	0.0	0.0	0.0	0.0	4.2
23/12/2009	11.8	37.9	24.8	0.0	0.0	0.0	0.0	4.2
24/12/2009	17.0	24.0	20.5	0.0	0.0	0.0	0.0	4.2
25/12/2009	12.9	22.2	17.5	0.0	0.0	0.0	0.0	4.2
26/12/2009	10.7	20.1	15.4	15.4	8.9	-0.5	0.5	4.7
27/12/2009	12.4	22.9	17.6	0.0	0.0	0.0	0.0	4.7
28/12/2009	11.8	22.7	17.2	0.0	0.0	0.0	0.0	4.7
29/12/2009	11.8	22.4	17.1	0.0	0.0	0.0	0.0	4.7
30/12/2009	13.6	35.6	24.6	0.0	0.0	0.0	0.0	4.7
31/12/2009	18.0	36.5	27.2	0.0	0.0	0.0	0.0	4.7
1/01/2010	17.1	18.3	17.7	0.0	0.0	0.0	0.0	4.7
2/01/2010	14.5	20.6	17.5	0.0	0.0	0.0	0.0	4.7
3/01/2010	13.1	18.9	16.0	16.0	9.5	-1.0	0.0	4.7
4/01/2010	11.3	23.6	17.5	0.0	0.0	0.0	0.0	4.7
5/01/2010	11.7	22.4	17.0	0.0	0.0	0.0	0.0	4.7
6/01/2010	11.1	20.8	15.9	15.9	9.4	-0.9	0.1	4.8
7/01/2010	10.3	21.9	16.1	0.0	0.0	0.0	0.0	4.8
8/01/2010	10.4	35.7	23.0	0.0	0.0	0.0	0.0	4.8
9/01/2010	16.6	35.3	25.9	0.0	0.0	0.0	0.0	4.8
10/01/2010	11.1	29.3	20.2	0.0	0.0	0.0	0.0	4.8
11/01/2010	16.3	42.9	29.6	0.0	0.0	0.0	0.0	4.8
12/01/2010	22.1	33.0	27.6	0.0	0.0	0.0	0.0	4.8
13/01/2010	15.3	20.8	18.0	0.0	0.0	0.0	0.0	4.8
14/01/2010	12.4	21.0	16.7	0.0	0.0	0.0	0.0	4.8
15/01/2010	14.4	24.6	19.5	0.0	0.0	0.0	0.0	4.8
16/01/2010	16.8	29.2	23.0	0.0	0.0	0.0	0.0	4.8
17/01/2010	12.0	19.5	15.7	15.7	9.2	-0.8	0.2	5.0
18/01/2010	9.4	19.0	14.2	14.2	7.7	0.4	0.4	5.4
19/01/2010	11.3	19.7	15.5	15.5	9.0	-0.6	0.4	5.9
20/01/2010	11.8	26.3	19.0	0.0	0.0	0.0	0.0	5.9
21/01/2010	15.0	26.3	20.6	0.0	0.0	0.0	0.0	5.9

Appendix 4 Anthocyanin Measurement Methodology

I. Method for Measurement of Anthocyanin

1. Analytical Instrument and Apparatus

Spectrophotometer

Erlenmeyer flask (200ml, attachable to reflux tube)

Reflux tube

Water bath (settable at 80 Celsius)

Measuring flask (100ml)

2. Reagent

- Hydrochloric acid (Highest quality)
- Methanol (Highest quality)

II. Analysis

1. Dispensing of Reagent

A) 2% solution of 32% Hydrochloric acid/ Methanol

Dilute hydrochloric acid with methanol (2% v/v)

i.e. 6.25 mL HCl brought up to 500 mL with methanol

2. Preparation of Analysis

Turn on Spectrophotometer and stabilize it.

3. Procedure of Analysis

a) Measure approximately 1 g of test portion (purple carrot juice Bx8) and put it into the Erlenmeyer flask at flat place. And dilute it with 60ml of A)

b) Attach the reflux tube to a) and reflux in a water bath at 80 Celsius for 30 minutes.

c) After cool down (20°C) pour into a measuring flask and add A) to make total 100ml.

d) Set Spectrophotometer at 538 nm and measure Absorbance of c). Zero against water

4. Calculation of the amount of Anthocyanin

Amount of Anthocyanin(mg%@Bx8) is calculated as below.

$$\text{Anthocyanin(mg\%)} = \frac{\text{Absorbance(538nm)} \times 10d \times 322.7 \times 100}{31400 \times \text{Amount of sample (g)}}$$