Project Number: VX00019

Development of a crop management program to improve the sugar-content and quality of rockmelons.

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Project Number: VX00019

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Media Summary

Applied Horticultural Research (AHR) and One Harvest have worked together on a successful project aimed at increasing the SSC in Rockmelon fruit.

The aim of the project was to develop agronomic techniques that could be used by growers to improve sugars and quality of Rockmelons.

The aim was to achieve 90% of fruit with a soluble solids concentration of at least 10%.

Experiments were conducted on the farms of the collaborators listed below as well as the University of Central Queensland, Rockhampton:

- Back O' Bourke Fruits (Bourke, NSW)
- Thurla Farms (Mildura, Vic)
- Bluey's Outback Farms (Kununurra, WA)
- Top Bananas (Humpty Doo, NT)
- Dodmil Park - Peter Dodson (Rockhampton, Qld)

The project has resulted in techniques which have allowed growers to increase fruit soluble solids (sugars) from 8.4% to 11.4 % with over 90% of the fruit above 10%.

The main techniques used to achieve these results were:

1. Maintain the soil between field capacity and refill point to the end of harvest – do not water stress at any stage from flowering to harvest
2. Maintain roots in a healthy condition
3. Provide balanced NPK and calcium nutrition to the plants
4. Select growing locations which ideally provide long sunny days with maximum temperature below 37 ^{o}C and cool nights.

Future R&D should focus on:

- Agronomy for personal watermelons
- Crop scheduling
- Improving internal fruit quality for value–added processed melon products
- Spacing and density work for all melons groups
- Timing of pollination to maximize yield
- Postharvest and supply chain temperature management

Technical Summary

The concept behind this project was to develop and test agronomic techniques capable of producing rockmelons with consistently high sugar content in the major melon growing regions in Australia. The project is complementary to the Near InfraRed Spectroscopy (NIRS) project which uses NIRS to screen rockmelons postharvest for internal sugar content. The primary aim of the project was to achieve a SSC level of 9% or more in 90% of the fruit produced. At the start of the project, 50% of fruit grown in Australia was below 8.7% SSC.

Trials were conducted at Kununurra, Bourke, Mildura, Rockhampton, at Humpty Doo and Central Qld University to test the effects of irrigation, mineral nutrition, plant spacing and density, crop load, varieties and foliar sprays. In addition, fruit SSC from the Sydney Market was measured every fortnight throughout 2004.

The key findings were:

- Plants should be maintained free of water stress from first flower until the end of harvest, including through the harvest period.
- Root health is critical in producing fruit with high sugars. The critical strategy is to start the crop cycle with a fully wetted soil profile, then water to field capacity when the soil moisture content falls to a predetermined refill point.
- Fruit soluble solids can be improved by removing small fruit that will not be harvested about 7 days before the start of harvest
- Plants should be kept supplied with sufficient N, P, K and Ca in balanced applications so that plants don't run out of nutrients before harvest.
- Fruit load controls vegetative plant growth.
- High N applications, more than 100 kg/ha N do not reduce flowering or fruit set.
- On the Sydney market in 2004, 46% of fruit samples were below 10% soluble solids.
- Growing locations which provide long sunny days with maximum temperature below 37 ^{o}C and cool nights provide the best conditions for sugar accumulation in the fruit.
- There is significant genetic potential to produce fruit with higher soluble solids than current standard varieties.

1. Introduction

Fruit quality and eating experience has an important effect on consumer satisfaction with a purchase and whether they make repeat purchases. The accepted wisdom is that if a consumer has a negative eating experience they are not likely to purchase that type of fruit gain for at least six weeks. It is important therefore to consistently preset consumers with a product of a quality that they find acceptable if sales are to be maintained or increased.

One criterion commonly used to assess fruit eating quality is soluble solids concentration (SSC) of the flesh. While there is some controversy about the value of SSC by itself as a measure of eating quality (Senesi, Lo Scalzo et al. 2002; Senesi, Di Cesare et al. 2005) and SSC includes all solutes, not just sugars (Burger et al. 2000), it remains a commonly used indicator of eating quality. Mutton et al. (1981) recommended a minimum SSC of 10%, while a U.S. standard recommends a minimum of 9.0% (Kader, 2002). The retail chains Coles and Woolworths in Australia use a value of more than 10% SSC as a threshold level to assess eating quality.

At the start of the project, 50% of the rockmelon fruit grown in Queensland were 8.7% SSC and virtually no of the fruit were above 10% SSC (K. Walsh pers. comm.). Other aspects of fruit quality which may affect the consumer's decision on whether to buy the fruit or not includes: fruit size; external skin appearance (pitting or brown spots); the extent of netting on the fruit surface; post harvest diseases and internal breakdown (Boylan 2000).

In early fruit development, rockmelon fruit use assimilate produced by photosynthesis to supply the requirements for fruit growth. It is not until the final two weeks of fruit development, after fruit expansion has ceased, that sugars accumulate in the fruit resulting in an increase in SSC. This carbohydrate partitioning is regulated by high soluble acid invertase activity during fruit growth and then by high sucrose phosphate synthase activity during the sugar accumulation phase (Lester et al., 2001).

Muskmelon do not accumulate significant amounts of starch, so all carbohydrate for fruit growth or sugar accumulation must come from current photosynthesis in the source leaves (Wein, 1997). Therefore any factors which impact to reduce the production of carbohydrate from photosynthesis (i.e. carbohydrate source) or which increase the use of carbohydrate by the plant (i.e. carbohydrate sink) are likely to reduce the overall fruit SSC level.

Factors which are likely to reduce the size of the carbohydrate sink are likely to reduce the SSC of fruit (Parry et al. 1993; Zhang et al. 1995). These include:

- water stress
- limited supply of plant nutrients
- capacity of the roots to supply water and/or nutrients to the shoot including root diseases
- foliage diseases which reduce effective leaf area
- weather conditions including light intensity/duration which may limit the rate of photosynthesis
- atmospheric CO_2 concentration.

Similarly, factors which increase the size of the carbohydrate sink are also likely to reduce the SSC of individual fruit. The main factor likely to affect sink size is fruit load per plant or per unit area. There may be some effect of planting density on fruit loads x the size of the carbohydrate source.

Water Stress: As rockmelon plants become water-stressed, stomata progressively close. The reduced stomatal aperture inhibits CO_2 movement into the leaf, slowing the rate of photosynthesis and sugar production in the source leaves.

Rockmelons however being adapted to dry conditions may be able to withstand a mild water stress before photosynthetic rate (hence photoassimilate supply) is significantly reduced (Cornic et al. 1992). Soil moisture content has been negatively correlated with soluble solids content (SSC) i.e. plants growing in drier soil have greater fruit SSC levels than plants growing in moist soil (Wells and Nugent 1980). This increase in fruit sugar levels is most pronounced when soil moisture levels are reduced within 5 days of harvest (Bouwkamp et al. 1978).

This finding has led to the practice of subjecting plants to water stress for the later phases of growth, well into the sucrose accumulation phase. Evidence suggests however, that water stressing plants is required only in the last 5 days of fruit development to produce higher fruit sugar levels. Subjecting plants to excessive water stress earlier in fruit development probably reduces potential fruit sugar levels by restricting photoassimilate supply. The balance between irrigation effects and growth on fruit quality need to be determined for the major melon growing regions in Australia.

Nutrient Supply: High nutrient levels, especially nitrogen are required for high soluble sugars in the fruit and good fruit netting (Pew and Gardner 1972; Nerson 1992). Leaf photosynthetic rate is very sensitive to plant nutrient levels (Muthuchelian 1992; Fichtner et al. 1993; Walker et al. 1993), especially nitrogen and would explain the correlation between optimal nutrition and high sugar accumulation in fruit. There is a perception that high nitrogen supply result in excessive vegetative growth at the expense of yield (fruit number and/or size), however the objective data may not support this idea (Huett 1996).

Calcium is critical in the development of high quality melons. Calcium deficiency can reduce SSC, netting, tolerance to chilling injury and fruit firmness (Sombrink et al. 1995). Calcium accumulation in the fruit occurs mainly in the first 20 days after anthesis, and sufficient calcium must be available to the developing fruit during this time. Late foliar calcium applications are ineffective at correcting calcium deficiency (Bernadec et al. 1996). Boron deficiency has a similar effect on fruit quality to calcium deficiency, and can be corrected by foliar boron applications up to 7 weeks after transplant (Sombrink et al. 1995). The relationship between nutrient supply, yield and fruit SSC needs to established.

Root system: Factors which limit the size or effectiveness of the root system are likely to have a negative effect on fruit SSC through limitations on water and/or nutrient supply to the shoot (Champaco, Martyn et al. 1993; Mertely, Martyn et al. 1993; Martyn and Miller 1996; Batten, Scholthof et al. 2000).

Foliage diseases: One effect of foliar diseases such as powdery and downy mildews is that they reduce effective leaf area for photosynthesis (Egel and Harmon 2001). Such a reduction in effective leaf area could be expected to reduce assimilation rate, hence the supply of carbohydrate available for the synthesis of fruit sugars.

Weather conditions, light and CO_2: The optimum ranges for flowering in *Cucumis melo* are 19-32 ^{o}C and 18-35 ^{o}C for fruit set (Maestro and Alvarez 1988; Hagiuda 1994; Ma, Hu et al. 1996). Temperatures for fruit development are 20-32 ^{o}C (optimum) with the lower and upper limits 20 ^{o}C and 35-40 ^{o}C respectively (Wacquant 1974; Wacquant 1989). Light levels in Australia are high, and on an individual leaf basis saturate the photosynthetic capacity. However, if the leaf area index is high, then shaded lower leaves may act as a carbohydrate sink. The atmospheric CO_2 concentration will affect photosynthetic rate, but provided the plants are grown outdoors, this should not be a relevant factor.

Crop Load: Valantin et al. (1998) showed that leaf cover is linked to the fruit load carried by the plant. If fruit are removed, e.g. leaving one fruit per plant, then leaf cover is increased by 30%, while the photosynthetic rate of individual leaves remains unaffected. This means that by reducing fruit load, an increase in photoassimilate production in the plant is possible. Such a thinning treatment has the potential to increase sugar accumulation in rockmelon fruits. Reducing the fruit load (i.e. number of fruit per plant) also results in more vegetative growth generally, in both shoots and roots and stimulates male flowering (El-Keblawry and Lovett-Doust 1996).

The hypothesis that fruit thinning increases fruit sugar content (% SSC) has been tested in preliminary trials in Kununurra, WA. At Bluey's Farm (Kununurra, WA), all but one fruit per vine was removed at either 10 days before harvest or 5 days before harvest in a replicated trial. This fruit thinning practice was considered by the grower to be commercially viable. At harvest, the % SSC in fruit was measured. As a result of the fruit thinning, fruit soluble solids (% SSC) content was increased significantly ($P<0.05$) from 9.9 ±0.2% to 11.9 ±0.2%, an increase of 21% (Long unpublished data).

Bees are commonly used for pollination in rockmelon crops. Eischen et al. (1994) found that pollination could be delayed by 6 days from the time of first female flowering with no loss of yield or fruit quality. The implication is that the introduction of bees could be delayed 6 days from the normal introduction time (first female flowers) with no adverse effects on production. If the female flowers are not pollinated, fruit do not develop (Gao et al. 1999). This presents the possibility of manipulating the number of fruit per vine by controlling pollination. Perhaps, by controlling the duration beehives are placed in the block, or by the strategic use of row covers, fruit set can be controlled without the need to thin fruit.

The use of Near Infrared Spectroscopy (NIRS) to measure rockmelon fruit SSC:
NIRS can be used to measure the SSC of rockmelon fruit (Guthrie, Liebenberg et al. 2006). The advantage of this method over destructive methods is that it has the potential to be used as a postharvest screening tool to separate fruit with an SSC over a certain threshold (say 10%) which can then be marketed as a premium grade fruit. This objective was the primary motivation for the project described in this report.

The concept behind this project was to develop and test methods which could be used to produce rockmelons with a soluble solids concentration above 10% in the major melon growing regions in Australia. The project was run in conjunction with a separate project aimed at using Near InfraRed Spectroscopy (NIRS) to screen rockmelons postharvest for internal sugar content.

The project was focused on field experiments designed to extend established agronomic techniques for rockmelon production and incorporate well-established principles of carbohydrate source-sink physiology.

The project will investigate soil moisture, nutrition and source-sink manipulation techniques and varieties to determine the best combination for optimal fruit quality and sugar levels in the major Australian rockmelon growing areas.

2. Materials and Methods for Yield and Quality

Yield Assessment: For each experiment, 2m long sections within each trial plot were marked and used for all data collection. Fruit were counted before the first harvest and harvested each day as they reached the “full slip” stage, defined as when a slight pressure is applied to the stalk, it pulls away from the fruit cleanly. At the end of the assessment period (7-10 days), all remaining fruit from the 2m section, was harvested, counted and weighed. SSC was determined using the method described above, the fruit was then cut longitudinally, and the cavity width measured. Flesh firmness was assessed using a 1 cm diameter tip on a standard penetrometer three times around the cavity in a position equidistant from the skin and the cavity. Taste was assessed as aromatic (A) or bland (B) and assessed using a subjective 1-5 rating where 1=Very poor; 2=Poor; 3=Acceptable; 4=Good; 5=Excellent. Skin background colour and flesh colour was also recorded.

Soluble Solids Assessment: Variations in SSC in a rockmelon fruit mean that sampling is the largest source of error in measuring SSC. The following method was developed by the non-Invasive assessment group at Central Queensland University led by Assoc Prof. Kerry Walsh.

The fruit was placed so that the ground spot was facing down, then a ca. 20 mm diameter core was taken from either side of the fruit, midway between the stem and distal ends (Fig. 1).

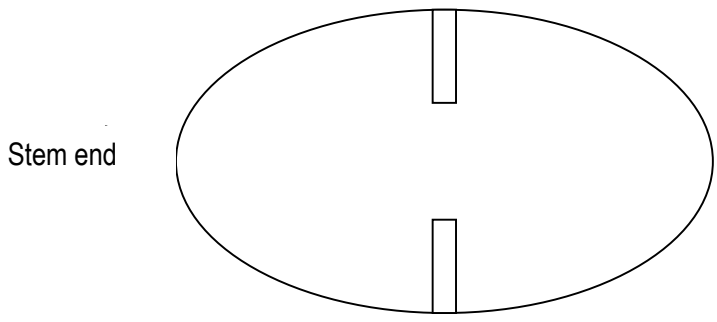


Figure 1. Looking from above the fruit with the ground spot facing down

The cores were laid on a cutting surface and the outer 8-10 mm of skin and green flesh removed. The cores could be stored in tubes overnight if capped to stop evaporation. The outer 1 cm (skin and green) were removed and the next 1 cm of flesh along the cores was sampled, then pressed in a garlic crusher and the juice collected into tubes before reading the SSC using a temperature compensating digital refractometer (Fig. 2). The refractometer was zeroed every 10 samples using distilled water at 20 ^{o}C and recalibrated if the distilled water was greater than 0 $\pm$0.2 ^{o} Brix.

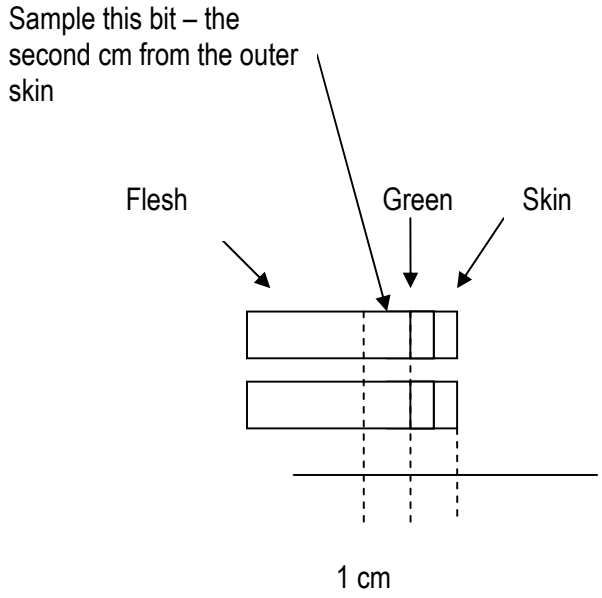


Figure 2. Sampling detail.

3. Variety Evaluations

Introduction

A large number of rockmelon and honeydew varieties were evaluated over a range of sites throughout the four years of the project. The primary objective of the variety work was to identify and evaluate new genetic material for consistently high SSC across the main growing climatic zones that would be required to provide all year round supply of fruit demanded by retailers.

Table 1 Sites were chosen to represent the following climatic regions.

Regions	Sites used during project
Winter – northern Australia	Kununurra 2002 Douglas Daly 2003 Darwin 2004
Spring and summer transition – central Australia	Bourke 2001/2 Cunnamulla 2002/3 Bourke 2003/4
Summer and autumn transition southern Victoria	Mildura 2003/4 Irymple 2005

For each site, promising varieties were obtained from the major seed companies in Australia as well as some seed directly from overseas.

Materials and Methods

At each site, plants were established by direct seedling, except for Darwin where they were established from transplants. Seed was sown by hand into 10m long plots, with 4 replications in completely randomised designs, except for the Irymple trial which was observational only and included an industry standard variety which was Hotshot (Syngenta) for Kununurra, Darwin and Douglas Daly, and Dubloon (Syngenta) for all other sites.

Crops were growing using the growers' standard agronomy, as part of the commercial crop. As fruit reached maturity, judged as "full slip", fruit were harvested by hand and assessed for yield and quality as described in section 2.

A summary of the varieties evaluated over the project is presented in Table 1.

Key yield and quality data was selected and presented in table 2 to give an overview summary. SEs were omitted for simplicity, but are available in a separate detailed summary of variety data by region.

The mean fruit soluble solids (Brix) data and yield data which came from replicated trials across all trial sites and varieties was grouped according to three production seasons/regions (winter, spring-->summer, summer-->autumn). The SSC data from each trial was then scaled against the standard variety in each trial, so that the standard variety SSC was forced to 10%. The scaled data is referred to as normalized SSC values. The standards were Hotshot for winter production and Dubloon for summer and shoulder seasons. An indicator value was then calculated as follows: if normalized Brix >10 and yield > 45 t/ha, then indicator=2; if either normalized Brix >10 or yield >45 then indicator =1; if normalized Brix<10 and yield <45 then indicator =0. The Selection indicator column shows *green* when score is 2, *yellow* when score is 1 and *red* when score is 0. The data was the sorted by selection indicator, then by Brix and then by yield. The normalized data and indicators is presented in Table 3.

Results and Discussion

The two key criteria for variety selection I this project were high SSC content of the fruit with high yields. Table 2 shows that 20 varieties, including the current industry standards have a normalized SSC >= 10% and with a yield of > 45 t/ha.

High normalized SSC values (>10 % SSC) are colour coded light green, and high yield (>45 t/ha) are color coded light yellow. This shows groups which split naturally into either high Brix (variable yield) or high yield (variable Brix), then the losers (red) are at the bottom. While this grouping was not an objective of the project, it is an interesting separation of traits (Table 2).

For the winter production regions, the best varieties were: ACX 9201, 437-2, YRM 3628 and RM 1147, 849 and Mel 9409 and Hotshot.

For either the spring → summer transition or the summer → autumn transition, the best varieties were: 437-2, YRM 3628, RM 1147, RM 1143, JTRM 820, 5801, JTRM 815, RM 1246, RM 1150, RM 1144, 849, RM 1155, RZ001, RM 1260, Mel 9409, 440-2, RM 1139 and Dubloon (Table 3).

Table 3 shows actual yield and SSC data for all trials plus the number of trials compared by region. Tables 4 to 12 then shows yield, fruit size and quality data for each trial. This comparative data can be important to seed companies for comparing varieties and for checking the characteristic of varieties that look promising in Table 2. The full set of variety data including statistics, all variable measured and photographs are included in a separate document which accompanies this report.

Table 2 – Normalised rockmelon SSC and yield data from 8 trial sites over three climatic zones. The light green cells show adjusted normalised SSC levels of 10 or more, yellow cells are standard varieties, cream cells are yields over 45 t/ha, bright green cells have both yield > 45 t/ha and normalised SSC > 10%, orange cells have either both yield > 45 t/ha or normalised SSC > 10%, and red cells have neither yield > 45 t/ha or normalised SSC > 10%.

Rockmelon Variety Summary

		Avg. Brix %										
		Normalised SSC (scores > 10 better than standard)										
		Winter			Spring --> Summer			Summer --> Autumn		Normalised		
Variety ID	Supplier	Kununurra	Douglas Daly	Darwin	Bourke	Cunnamulla	Bourke	Mildura	Irymple	Mean	Mean	Selection
		2002	2003	2004	2001-2002	2002-2003	2003-2004	2003-2004	2005	SSC	Yield	Indicator
ACX 9201	Abbott and Cobb			14.0					12.2	13.1	47.1	
437-2	SPS		16.7			11.1	10.8			12.9	51.5	
YRM 3628	Terranova/Yates	11.3								11.3	60.8	
RM 1147	Syngenta		13.8			11.5	10.2	8.6		11.0	45.4	
RM 1143	Syngenta					10.9				10.9	54.0	
JTRM 820	Jarit					10.8				10.8	48.5	
5801	SPS								10.6	10.6	73.5	
JTRM 815	Jarit					10.5				10.5	62.7	
RM 1246	Syngenta								10.5	10.5	48.0	
RM 1150	Syngenta					10.3				10.3	49.0	
RM 1144	Syngenta					10.2				10.2	51.1	
849	SPS	10.3			11.7	8.4				10.1	50.2	
RM 1155	Syngenta					10.1		10.2		10.1	60.9	
RZ001	Rijk Zwaan				10.1					10.1	58.5	
RM 1260	Syngenta								10.1	10.1	46.9	
Mel 9409	Lefroy Valley			12.4				7.7		10.0	46.3	
Hotshot	Syngenta	10.0	10.0	10.0	9.9	10.2				10.0	47.9	
440-2	SPS					10.0				10.0	54.2	
RM 1139	Syngenta					10.0				10.0	50.7	
Dubloon	Syngenta				10.0	10.0	10.0	10.0	10.0	10.0	49.2	
LX2481	Terranova/Yates	15.4				11.4				13.4	25.4	
ACX 3200SS XLT	Abbott and Cobb			13.4						13.4	15.9	
99-01-CHR	CSIRO				13.2					13.2	32.4	
RM 1149	Syngenta		15.2				10.2			12.7	44.6	
RZ004	Rijk Zwaan				12.6					12.6	40.2	
Pegaso	Claus								12.5	12.5	20.6	
Solreal	Syngenta		14.4				10.4			12.4	37.3	
ACX 2076	Abbott and Cobb								12.4	12.4		
516-8	SPS		13.2				11.5			12.4	40.9	
Aneto	Rijk Zwaan				12.4					12.4	22.4	
RM 1248	Syngenta								12.3	12.3	13.4	
RM 1233	Syngenta			12.9					11.5	12.2	23.4	
571-1	SPS	12.1								12.1	24.6	
RM 1146	Syngenta		14.2			13.7	11.0	9.8	11.0	12.0	33.2	
Tejo	Rijk Zwaan				12.0					12.0	26.6	
ACX 2078	Abbott and Cobb			12.6					11.3	11.9	42.9	
HD 1422	SPS								11.7	11.7	40.3	
Gold Express	Syngenta		16.2			10.1	8.5			11.6	42.1	
RM 1217	Syngenta			12.1					11.0	11.5	18.1	
586-1	SPS	11.3	14.0	12.2		9.8	10.6			11.5	42.1	
HD 581-4	SPS								11.5	11.5	32.9	
Tenki	Lefroy Valley				11.5					11.5	24.0	
ACX 1520SS XLT	Abbott and Cobb			11.4						11.4	42.4	
856-3	SPS			13.0					9.8	11.4	35.8	
Esteem	Syngenta		14.3			13.4	9.6	8.2	10.8	11.3	34.5	
Chantel	Syngenta								11.3	11.3	26.4	
Kooba	Lefroy Valley	9.9			12.0	11.8				11.2	35.2	
JTRM 843	Jarit								11.2	11.2	33.0	
Southern Cross	Syngenta								11.2	11.2	27.7	
RZ003	Rijk Zwaan				11.2					11.2	27.6	
633-1	SPS	10.9								10.9	32.8	
Solid Gold	Syngenta								10.8	10.8	41.4	
RM 1253	Syngenta								10.8	10.8	23.9	
5238	SPS				10.8					10.8	35.2	
Eastern Star	Syngenta			10.8						10.8	41.5	
Colorado	Syngenta			10.8						10.8	10.6	
CLX 2777	Lefroy Valley	9.8			12.2	10.1				10.7	35.4	
RM 1211	Syngenta			10.7						10.7	33.4	
Delicious	Syngenta								10.6	10.6	32.0	
302-3	SPS			13.6			8.1		10.1	10.6	34.1	
Galliano	SPS	10.6								10.6	14.1	
svr 1460-4099	Seminis			10.7			9.8	11.3	10.5	10.6	32.2	
RM 1250	Syngenta								10.6	10.6	39.9	
5168	SPS ?	11.5				9.6				10.5	33.0	
Arpege	Rijk Zwaan	10.6				10.5				10.5	29.5	
611-0	SPS	10.5				10.6				10.5	42.5	
Comet	SPS			10.9					10.2	10.5	43.9	
Luxo	Lefroy Valley	11.3			12.4	7.9				10.5	25.7	

Ultra Sweet	Terranova/Yates								10.5	10.5	28.3	
Tobbia	Rijk Zwaan	10.1			11.7	9.4				10.4	41.7	
RM 0855	Syngenta	9.8				10.9				10.3	40.6	
PX 6391-3108	Seminis								10.3	10.3	27.7	
YRM 3621	Terranova/Yates	10.1				10.4				10.3	43.1	
El Dorado	Syngenta	10.2								10.2	30.6	
Aitana	Rijk Zwaan	10.5				9.8				10.1	41.6	
5298	SPS				10.1					10.1	23.3	
994002	Hendersons	9.7				10.4				10.0	29.7	
Aubrac	Rijk Zwaan				10.0					10.0	28.2	
RM 1165	Syngenta								10.0	10.0	24.2	
242-1	SPS	10.0								10.0	20.3	
JTRM 819	Jarit					11.5	9.6	8.6		9.9	45.8	
JTRM 808	Jarit			9.9						9.9	52.5	
Mel 1774	Lefroy Valley	10.2				8.7				9.5	45.3	
RM 1249	Syngenta								9.4	9.4	62.9	
RM 1141	Syngenta					9.4				9.4	79.7	
441-2	SPS					9.4				9.4	69.2	
Hi-Line								9.3		9.3	48.0	
RM 0994	Syngenta	8.7				9.9				9.3	55.7	
RM 1029	Syngenta	10.0				8.6				9.3	50.5	
svr 1461-1013	Seminis						9.2			9.2	66.7	
RM 0072	Syngenta					9.2				9.2	66.6	
RM 1142	Syngenta					9.2				9.2	49.1	
JTRM 8451	Jarit								9.0	9.0	58.2	
ACX 30 ES XLT	Abbott and Cobb			8.9						8.9	60.1	
JTHD 902	Jarit					8.9				8.9	48.6	
Yenda F1	Lefroy Valley				8.7					8.7	50.6	
JRTM 827	Jarit					8.7				8.7	79.3	
JTRM 806	Jarit				8.1	9.1				8.6	47.4	
JTHD 901	Jarit					8.5				8.5	77.1	
Mel 3570	Lefroy Valley			8.5						8.5	65.3	
Sweetheart	Jarit						9.3	7.6	8.4	8.4	45.8	
JTRM 826	Jarit					8.3				8.3	72.5	
Stirling	Terranova/Yates				8.0					8.0	58.6	
JTHD 904	Jarit					7.8				7.8	49.5	
JTHD 818	Jarit					7.7				7.7	68.0	
536-3	SPS							7.5		7.5	53.1	
Durack	Terranova/Yates	8.7		11.1	10.6		9.4			10.0	28.7	
Colusa	Lefroy Valley	9.8		10.7		8.6				9.7	43.7	
PX 0439-1649	Seminis								9.6	9.6	29.4	
628-1	SPS	9.5								9.5	26.3	
694-9	SPS	9.5								9.5	17.3	
Mel 34-531	Rijk Zwaan	9.5								9.5	16.7	
RM 1140	Syngenta					9.5				9.5	39.9	
500-9	SPS	10.6				8.3				9.4	36.7	
632-1	SPS	9.4								9.4	22.0	
YRM 3606	Terranova/Yates	9.4								9.4	19.1	
Pablo	SPS	8.5			10.2		9.5			9.4	41.8	
RM 1194	Syngenta						9.7	9.1		9.4	32.8	
RM 1236	Syngenta			9.3						9.3	37.1	
570-1	SPS	9.3								9.3	36.6	
CLX 2752	Lefroy Valley	9.3								9.3	29.1	
502-9	SPS	9.2								9.2	24.7	
RM 1261	Syngenta								9.1	9.1	32.7	
Chardonnay	Hendersons				9.1					9.1	27.3	
438-2	SPS					9.0				9.0	41.6	
DRT 7777	Rijk Zwaan	8.9								8.9	24.5	
631-1	SPS	8.7								8.7	33.9	
NY 62100	Rijk Zwaan	8.7								8.7	26.9	
Sahara	SPS				8.7					8.7	31.3	
Mel 1085	Lefroy Valley	8.5								8.5	18.4	
Frontier				9.0				8.0		8.5	13.7	
Isabella	Seminis								8.3	8.3	23.2	
Sienna	Terranova/Yates								8.2	8.2	26.0	
Northern Sky	Syngenta							8.0		8.0		
JTRM 847	Jarit								8.0	8.0	24.0	
YRM 3607	Terranova/Yates	7.9								7.9	17.8	
569-1	SPS	7.4								7.4	33.0	
Portola F1	Lefroy Valley							7.3		7.3	40.2	
RM 0853	Syngenta	7.1								7.1	27.9	

Table 3 Rockmelon SSC data over three climatic zones. Mean SSC data from field trials over three climatic regions.

Rockmelon Variety Summary

		Avg. Brix %									
		Winter			Spring --> Summer			Summer --> Autumn		Overall	
Variety ID	Supplier	Kununurra	Douglas Daly	Darwin	Bourke	Cunnamulla	Bourke	Mildura	Irymple	Mean	Number
		2002.0	2003.0	2004.0	2001-2002	2002-2003	2003-2004	2003-2004	2005.0	SSC %	of trials
Pegaso	Claus								15.8	15.8	1
ACX 2076	Abbott and Cobb								15.6	15.6	1
RM 1248	Syngenta								15.5	15.5	1
HD 1422	SPS								14.8	14.8	1
HD 581-4	SPS								14.5	14.5	1
Chantel	Syngenta								14.2	14.2	1
ACX 9201	Abbott and Cobb			12.9					15.4	14.2	2
JTRM 843	Jarit								14.1	14.1	1
Southern Cross	Syngenta								14.1	14.1	1
Solid Gold	Syngenta								13.6	13.6	1
RM 1253	Syngenta								13.6	13.6	1
99-01-CHR	CSIRO				13.5					13.5	1
5801	SPS								13.4	13.4	1
Delicious	Syngenta								13.4	13.4	1
RM 1250	Syngenta								13.3	13.3	1
RM 1246	Syngenta								13.2	13.2	1
Ultra Sweet	Terranova/Yates								13.2	13.2	1
RM 1233	Syngenta			11.9					14.5	13.2	2
PX 6391-3108	Seminis								13.0	13.0	1
RZ004	Rijk Zwaan				12.9					12.9	1
ACX 2078	Abbott and Cobb			11.6					14.2	12.9	2
RM 1146	Syngenta		11.5			13.6	11.7	13.0	13.9	12.7	5
RM 1260	Syngenta								12.7	12.7	1
RM 1165	Syngenta								12.6	12.6	1
Aneto	Rijk Zwaan				12.6					12.6	1
RM 1217	Syngenta			11.1					13.9	12.5	2
LX2481	Terranova/Yates	13.4				11.3				12.4	2
Hi-Line								12.3		12.3	1
ACX 3200SS XLT	Abbott and Cobb			12.3						12.3	1
Tejo	Rijk Zwaan				12.2					12.2	1
856-3	SPS			12.0					12.3	12.2	2
PX 0439-1649	Seminis								12.1	12.1	1
svr 1460-4099	Seminis			9.8			10.4	14.9	13.2	12.1	4
437-2	SPS		13.5			11.0	11.5			12.0	3
Esteem	Syngenta		11.6			13.3	10.2	10.8	13.6	11.9	5
RM 1249	Syngenta								11.9	11.9	1
Tenki	Lefroy Valley				11.7					11.7	1
RM 1155	Syngenta					10.0		13.4		11.7	2
RM 1149	Syngenta		12.3				10.8			11.6	2
RM 1261	Syngenta								11.5	11.5	1
516-8	SPS		10.7				12.2			11.5	2
Comet	SPS			10.0					12.8	11.4	2
RZ003	Rijk Zwaan				11.4					11.4	1
Solreal	Syngenta		11.7				11.0			11.4	2
JTRM 8451	Jarit								11.3	11.3	1
Dubloon	Syngenta				10.2	9.9	10.6	13.2	12.6	11.3	5
302-3	SPS			12.5			8.6		12.7	11.3	3
RM 1147	Syngenta		11.2			11.4	10.8	11.4		11.2	4
RM 1194	Syngenta						10.3	12.0		11.2	2
JTRM 819	Jarit					11.4	10.2	11.4		11.0	3
5238	SPS				11.0					11.0	1
Kooba	Lefroy Valley	8.6			12.2	11.7				10.8	3
RM 1143	Syngenta					10.8				10.8	1
Mel 9409	Lefroy Valley			11.4				10.1		10.8	2
JTRM 820	Jarit					10.7				10.7	1
Gold Express	Syngenta		13.1			10.0	9.0			10.7	3
586-1	SPS	9.8	11.3	11.2		9.7	11.2			10.6	5
Northern Sky	Syngenta							10.6		10.6	1
ACX 1520SS XLT	Abbott and Cobb			10.5						10.5	1
571-1	SPS	10.5								10.5	1
JTRM 815	Jarit					10.4				10.4	1
Isabella	Seminis								10.4	10.4	1
CLX 2777	Lefroy Valley	8.5			12.4	10.0				10.3	3
RZ001	Rijk Zwaan				10.3					10.3	1
Sienna	Terranova/Yates								10.3	10.3	1

5298	SPS				10.3					10.3	1
RM 1150	Syngenta					10.2				10.2	1
Aubrac	Rijk Zwaan				10.2					10.2	1
Sweetheart	Jarit						9.9	10.0	10.6	10.2	3
RM 1144	Syngenta					10.1				10.1	1
JTRM 847	Jarit								10.1	10.1	1
Luxo	Lefroy Valley	9.8			12.6	7.8				10.1	3
Tobbia	Rijk Zwaan	8.8			11.9	9.3				10.0	3
440-2	SPS					9.9				9.9	1
536-3	SPS							9.9		9.9	1
RM 1139	Syngenta					9.9				9.9	1
Eastern Star	Syngenta			9.9						9.9	1
Colorado	Syngenta			9.9						9.9	1
svr 1461-1013	Seminis						9.8			9.8	1
YRM 3628	Terranova/Yates	9.8								9.8	1
611-0	SPS	9.1				10.5				9.8	2
RM 1211	Syngenta			9.8						9.8	1
Arpege	Rijk Zwaan	9.2				10.4				9.8	2
5168	SPS ?	10.0				9.5				9.8	2
849	SPS	9.0			11.9	8.3				9.7	3
Portola F1	Lefroy Valley							9.7		9.7	1
RM 0855	Syngenta	8.5				10.8				9.7	2
Durack	Terranova/Yates	7.6		10.2	10.8		10.0			9.7	4
YRM 3621	Terranova/Yates	8.8				10.3				9.6	2
633-1	SPS	9.5								9.5	1
RM 1140	Syngenta					9.4				9.4	1
Frontier				8.3				10.5		9.4	2
Aitana	Rijk Zwaan	9.1				9.7				9.4	2
994002	Hendersons	8.4				10.3				9.4	2
RM 1141	Syngenta					9.3				9.3	1
441-2	SPS					9.3				9.3	1
Chardonnay	Hendersons				9.3					9.3	1
Pablo	SPS	7.4			10.4		10.1			9.3	3
Hotshot	Syngenta	8.7	8.1	9.2	10.1	10.1				9.2	5
Galliano	SPS	9.2								9.2	1
RM 0072	Syngenta					9.1				9.1	1
JTRM 808	Jarit			9.1						9.1	1
RM 1142	Syngenta					9.1				9.1	1
Colusa	Lefroy Valley	8.5		9.8		8.5				8.9	3
Yenda F1	Lefroy Valley				8.9					8.9	1
438-2	SPS					8.9				8.9	1
Sahara	SPS				8.9					8.9	1
El Dorado	Syngenta	8.9								8.9	1
JTHD 902	Jarit					8.8				8.8	1
Mel 1774	Lefroy Valley	8.9				8.6				8.8	2
RM 0994	Syngenta	7.6				9.8				8.7	2
500-9	SPS	9.2				8.2				8.7	2
242-1	SPS	8.7								8.7	1
JTRM 806	Jarit				8.3	9.0				8.7	2
JRTM 827	Jarit					8.6				8.6	1
RM 1029	Syngenta	8.7				8.5				8.6	2
RM 1236	Syngenta			8.6						8.6	1
JTHD 901	Jarit					8.4				8.4	1
628-1	SPS	8.3								8.3	1
694-9	SPS	8.3								8.3	1
Mel 34-531	Rijk Zwaan	8.3								8.3	1
JTRM 826	Jarit					8.2				8.2	1
ACX 30 ES XLT	Abbott and Cobb			8.2						8.2	1
Stirling	Terranova/Yates				8.2					8.2	1
632-1	SPS	8.2								8.2	1
YRM 3606	Terranova/Yates	8.2								8.2	1
570-1	SPS	8.1								8.1	1
CLX 2752	Lefroy Valley	8.1								8.1	1
502-9	SPS	8.0								8.0	1
Mel 3570	Lefroy Valley			7.8						7.8	1
JTHD 904	Jarit					7.7				7.7	1
DRT 7777	Rijk Zwaan	7.7								7.7	1
JTHD 818	Jarit					7.6				7.6	1
631-1	SPS	7.6								7.6	1
NY 62100	Rijk Zwaan	7.6								7.6	1
Mel 1085	Lefroy Valley	7.4								7.4	1
YRM 3607	Terranova/Yates	6.9								6.9	1
569-1	SPS	6.4								6.4	1
RM 0853	Syngenta	6.2								6.2	1

Table 4. Rockmelon Yield data over three climatic zones.

Rockmelon Variety Summary

Yield (t/ha)

		Winter			Spring --> Summer			Summer --> Autumn		Mean
Variety ID	**Supplier**	**Kununurra**	**Douglas Daly**	**Darwin**	**Bourke**	**Cunnamulla**	**Bourke**	**Mildura**	**Irymple**	**Overall**
		2002.0	**2003.0**	**2004**	**2001-2002**	**2002-2003**	**2003-2004**	**2003-2004**	**2005.0**	**Yield**
RM 1141	Syngenta					79.7				79.7
JRTM 827	Jarit					79.3				79.3
JTHD 901	Jarit					77.1				77.1
5801	SPS								73.5	73.5
JTRM 826	Jarit					72.5				72.5
441-2	SPS					69.2				69.2
JTHD 818	Jarit					68.0				68.0
svr 1461-1013	Seminis						66.7			66.7
RM 0072	Syngenta					66.6				66.6
Mel 3570	Lefroy Valley			65.3						65.3
RM 1249	Syngenta								62.9	62.9
JTRM 815	Jarit					62.7				62.7
RM 1155	Syngenta					66.8		54.9		60.9
YRM 3628	Terranova/Yates	60.8								60.8
ACX 30 ES X	Abbott and Cobb			60.1						60.1
Stirling	Terranova/Yates				58.6					58.6
RZ001	Rijk Zwaan				58.5					58.5
JTRM 8451	Jarit								58.2	58.2
Dubloon	Syngenta					48.7	49.6		73.1	57.1
RM 0994	Syngenta	35.2				76.2				55.7
440-2	SPS					54.2				54.2
RM 1143	Syngenta					54.0				54.0
536-3	SPS							53.1		53.1
JTRM 808	Jarit			52.5						52.5
437-2	SPS		35.6			47.9	71.1			51.5
RM 1144	Syngenta					51.1				51.1
RM 1139	Syngenta					50.7				50.7
Yenda F1	Lefroy Valley				50.6					50.6
RM 1029	Syngenta	36.6				64.4				50.5
849	SPS	24.6			68.5	57.4				50.2
JTHD 904	Jarit					49.5				49.5
RM 1142	Syngenta					49.1				49.1
RM 1150	Syngenta					49.0				49.0
JTHD 902	Jarit					48.6				48.6
JTRM 820	Jarit					48.5				48.5
RM 1246	Syngenta								48.0	48.0
Hi-Line								48.0		48.0
Hotshot	Syngenta	33.7		42.7		67.3				47.9
JTRM 806	Jarit				30.2	64.6				47.4
ACX 9201	Abbott and Cobb			28.9					65.3	47.1
RM 1260	Syngenta								46.9	46.9
Mel 9409	Lefroy Valley			57.6				34.9		46.3
JTRM 819	Jarit					57.2	42.2	38.1		45.8
Sweetheart	Jarit						72.0	31.6	33.8	45.8
RM 1147	Syngenta		50.2			46.1	32.3	53.0		45.4
Mel 1774	Lefroy Valley	32.2				58.3				45.3
RM 1149	Syngenta		40.8				48.3			44.6
Comet	SPS			49.2					38.5	43.9
Colusa	Lefroy Valley	34.1		48.4		48.7				43.7
YRM 3621	Terranova/Yates	30.1				56.1				43.1
ACX 2078	Abbott and Cobb			51.5					34.3	42.9
611-0	SPS	19.6				65.3				42.5
ACX 1520SS	Abbott and Cobb			42.4						42.4
586-1	SPS	17.6	41.8	30.1		46.6	74.5			42.1
Gold Express	Syngenta		21.8			56.6	47.8			42.1
Pablo	SPS	32.0			26.0		67.3			41.8
Tobbia	Rijk Zwaan	18.9			37.2	69.0				41.7
438-2	SPS					41.6				41.6
Aitana	Rijk Zwaan	26.2				56.9				41.6
Eastern Star	Syngenta			41.5						41.5
Solid Gold	Syngenta								41.4	41.4
516-8	SPS		28.8				53.0			40.9
RM 0855	Syngenta	28.4				52.7				40.6
HD 1422	SPS								40.3	40.3
RZ004	Rijk Zwaan				40.2					40.2

Portola F1	Lefroy Valley							40.2		40.2
RM 1250	Syngenta								39.9	39.9
RM 1140	Syngenta					39.9				39.9
Solreal	Syngenta		40.0				34.5			37.3
RM 1236	Syngenta			37.1						37.1
500-9	SPS	17.4				56.0				36.7
570-1	SPS	36.6								36.6
856-3	SPS			51.7					19.9	35.8
CLX 2777	Lefroy Valley	16.3			42.1	47.9				35.4
5238	SPS				35.2					35.2
Kooba	Lefroy Valley	29.4			33.6	42.5				35.2
Esteem	Syngenta		36.2			30.4	46.1	26.3	33.6	34.5
302-3	SPS			36.3			37.8		28.3	34.1
631-1	SPS	33.9								33.9
RM 1211	Syngenta			33.4						33.4
RM 1146	Syngenta		36.1			27.0	38.2	39.1	25.4	33.2
JTRM 843	Jarit								33.0	33.0
5168	SPS ?	20.5				45.5				33.0
569-1	SPS	33.0								33.0
HD 581-4	SPS								32.9	32.9
633-1	SPS	32.8								32.8
RM 1194	Syngenta						30.0	35.5		32.8
RM 1261	Syngenta								32.7	32.7
99-01-CHR	CSIRO				32.4					32.4
svr 1460-4099	Seminis			25.9			58.2	25.7	19.0	32.2
Delicious	Syngenta								32.0	32.0
Sahara	SPS				31.3					31.3
El Dorado	Syngenta	30.6								30.6
994002	Hendersons	27.4				32.0				29.7
Arpege	Rijk Zwaan	12.3				46.6				29.5
PX 0439-1649	Seminis								29.4	29.4
CLX 2752	Lefroy Valley	29.1								29.1
Durack	Terranova/Yates	24.4		11.3			50.5			28.7
Ultra Sweet	Terranova/Yates								28.3	28.3
Aubrac	Rijk Zwaan				28.2					28.2
RM 0853	Syngenta	27.9								27.9
Southern Cros	Syngenta								27.7	27.7
PX 6391-3108	Seminis								27.7	27.7
RZ003	Rijk Zwaan				27.6					27.6
Chardonnay	Hendersons				27.3					27.3
NY 62100	Rijk Zwaan	26.9								26.9
Tejo	Rijk Zwaan				26.6					26.6
Chantel	Syngenta								26.4	26.4
628-1	SPS	26.3								26.3
Sienna	Terranova/Yates								26.0	26.0
Luxo	Lefroy Valley	16.0			31.2	30.0				25.7
LX2481	Terranova/Yates	20.9				29.8				25.4
502-9	SPS	24.7								24.7
571-1	SPS	24.6								24.6
DRT 7777	Rijk Zwaan	24.5								24.5
RM 1165	Syngenta								24.2	24.2
Tenki	Lefroy Valley				24.0					24.0
JTRM 847	Jarit								24.0	24.0
RM 1253	Syngenta								23.9	23.9
RM 1233	Syngenta			17.5					29.3	23.4
5298	SPS				23.3					23.3
Isabella	Seminis								23.2	23.2
Aneto	Rijk Zwaan				22.4					22.4
632-1	SPS	22.0								22.0
Pegaso	Claus								20.6	20.6
242-1	SPS	20.3								20.3
YRM 3606	Terranova/Yates	19.1								19.1
Mel 1085	Lefroy Valley	18.4								18.4
RM 1217	Syngenta			18.3					17.8	18.1
YRM 3607	Terranova/Yates	17.8								17.8
694-9	SPS	17.3								17.3
Mel 34-531	Rijk Zwaan	16.7								16.7
ACX 3200SS	Abbott and Cobb			15.9						15.9
Galliano	SPS	14.1								14.1
Frontier				27.3				0.0		13.7
RM 1248	Syngenta								13.4	13.4
Colorado	Syngenta			10.6						10.6

Table 5. Region 1 Winter – northern Australia *Kununurra 2002*

Variety	Supplier	SSC (%)	Yield (kg/ha)	Fruit wt (kg)	Size grade
LX2481	SPS	13.4	20.9	1.0	13
571-1	SPS	10.5	24.6	1.6	8
5168	SPS	10.0	20.5	1.4	10
586-1	SPS	9.8	17.6	1.2	11
Luxo	Lefroy Valley	9.8	16.0	1.1	13
633-1	SPS	9.5	32.8	1.6	8
Galliano	SPS	9.2	14.1	0.9	14
Arpege	Rjik Zwaan	9.2	12.3	0.8	17
500-9	SPS	9.2	17.4	1.2	12
611-0	SPS	9.1	19.6	1.0	14
Aitana	Rjik Zwaan	9.1	26.2	0.7	18
SPS 849	SPS	9.0	24.6	1.4	9
Mel 1774	Lefroy Valley	8.9	32.2	1.6	8
Eldorado	Syngenta	8.9	30.6	2.4	5
Durack	Yates	8.8	24.4	1.2	11
Tobbia	Rjik Zwaan	8.8	18.9	1.3	11
242-1	SPS	8.7	20.3	1.4	10
Hotshot	Syngenta	8.7	33.7	1.7	8
RM 1029	Syngenta	8.7	36.6	2.1	6
Kooba F1	Lefroy Valley	8.6	29.4	1.0	14
Colusa	Lefroy Valley	8.5	34.1	1.7	8
CLX 2777	Lefroy Valley	8.5	16.3	1.1	12
RM 0855	Syngenta	8.5	28.4	1.6	8
994002	Henderson	8.4	27.4	1.6	8
628-1	SPS	8.3	26.3	1.2	11
Mel 34-531	Rjik Zwaan	8.3	16.7	0.7	18
694-9	SPS	8.3	17.3	1.0	14
632-1	SPS	8.2	22.0	1.5	9
YRM 3606	Yates	8.2	19.1	1.1	12
570-1	SPS	8.1	36.6	1.6	8
CLX 2752	Lefroy Valley	8.1	29.1	1.9	7
502-9	SPS	8.0	24.7	2.0	7
DRT 7777	Rjik Zwaan	7.7	24.5	1.4	9
YRM 3621	Yates	7.7	30.1	1.5	9
YRM 3628	Yates	7.6	32.1	1.6	8
NY-62100	Rjik Zwaan	7.6	26.9	1.3	10
631-1	SPS	7.6	33.9	1.5	9
RM 0994	Syngenta	7.6	35.2	2.8	4
Pablo	SPS	7.4	32.0	1.6	8
Mel 1085	Lefroy Valley	7.4	18.4	1.2	11
YRM 3607	Yates	6.9	17.8	1.0	13
569-1	SPS	6.4	33.0	1.6	8
RM 0853	Syngenta	6.2	27.9	1.4	10

Table 6 Region 1 Winter – northern Australia *Douglas Daly 2003*

Variety	Supplier	SSC (%)	Yield (kg/ha)	Fruit wt (kg)	Size grade	Maturity	Firmness 1-10 scale
437-2	SPS	13.5	35.6	1.3	10	Late	8
1151	Syngenta	13.1	21.8	1.0	14	Mid	6
1149	Syngenta	12.3	40.8	1.0	14	Mid	7
1193 (Solreal)	Syngenta	11.7	40.0	1.1	13	Mid	6
1145 (Esteem)	Syngenta	11.5	36.2	0.9	15	Mid	7
1146	Syngenta	11.5	36.1	0.8	17	Mid	7
586-1	SPS	11.3	41.8	1.3	10	Mid	10
1147	Syngenta	11.2	50.2	1.1	13	Mid	7
516-8	SPS	10.7	28.8	1.2	12	Late	8

Table 7 Region 1 Winter – northern Australia *Darwin 2004*

Variety	Supplier	SSC (%)	Yield (kg/ha)	Fruit wt (kg)	Size grade	Firmness (kg/cm2)
ACX 9201	Abbott and Cobb	12.9	28.9	0.9	15	7.2
SPS 302-3	SPS	12.5	36.3	0.9	15	4.0
ACX 3200SS XLT	Abbott and Cobb	12.3	15.9	0.7	18	6.0
SPS 856-3	SPS	12.0	51.7	1.3	10	6.6
RM1233	Syngenta	11.9	17.5	0.8	17	3.8
ACX 2078	Abbott and Cobb	11.6	51.5	1.2	11	8.5
Rock Mel 9409	Leroy Valley	11.4	57.6	1.3	10	7.7
SPS 586-1	SPS	11.2	30.1	1.2	12	6.0
RM1217	Syngenta	11.1	18.3	0.9	15	5.7
ACX 1520SS XLT	Abbott and Cobb	10.5	42.4	0.7	21	7.3
Durack	Terra Nova	10.2	11.3	1.4	10	6.8
Comet	SPS	10.0	49.2	1.2	11	8.8
Colorado	Syngenta	9.9	10.6	1.9	7	5.0
Eastern Star	Syngenta	9.9	41.5	1.5	9	5.9
RM1211	Syngenta	9.8	33.4	1.0	14	4.4
SVR 1460-4099	Seminis	9.8	25.9	1.2	11	6.8
Colusa	Lefroy Valley	9.8	48.4	1.8	7	4.0
Hotshot	Syngenta	9.2	42.7	1.8	7	5.7
JTRM 808	Jarit	9.1	52.5	2.3	5	8.2
RM1236	Syngenta	8.6	37.1	0.8	17	3.3
Frontier		8.3	27.3	1.6	8	5.5
ACX 30 ES - XLT	Abbott and Cobb	8.2	60.1	1.8	7	8.7
Rock Mel 3570	Leroy Valley	7.8	65.3	1.9	7	5.1

Table 8. Region 2 Spring and summer transition – central Australia - *Bourke 2002*

Variety	Supplier	SSC (%)	Yield (kg/ha)	Fruit wt (kg)	Size grade	Maturity
99-01 CHR	CSIRO	13.1	32.4	1.85	7	2
RZ004	RZ	12.5	40.2	1.15	12	4
Luxo-1	LV	12.2	31.2	1.56	8	3
Aneto	RZ	12.2	22.4	1.12	12	6
CLX 2777	LV	12	42.1	1.68	8	4
Kooba F1	LV	11.8	33.6	1.49	9	1
TEJO	RZ	11.8	26.6	1.52	9	6
SPS 849	SPS	11.5	68.5	2.74	5	6
Tobbia	RZ	11.5	37.2	1.35	10	2
Tenkei	LV	11.3	24	1.07	13	5
RZ003	RZ	11	27.6	1.11	12	-2
SPS 5238	SPS	10.6	35.2	1.28	10	0
JTRM 802*	Jarit	10.5	64.2	1.43	9	2
Durack	Yates	10.4	57.6	1.77	7	3
Pablo	SPS	10	26	1.48	9	-2
RZ001	RZ	9.9	58.5	1.95	7	1
SPS 5298	SPS	9.9	23.3	1.04	13	5
Dubloon	Novartis	9.8	32.6	1.3	10	0
Aubrac	RZ	9.8	28.2	1.41	9	1
HotShot	Novartis	9.7	32	1.6	8	-2
Colusa F1	LV	9.3	75.5	2.32	6	-1
Chardonnay	Hend.	8.9	27.3	1.21	11	-1
Yenda F1	LV	8.5	50.6	2.53	5	-2
Sahara	SPS	8.5	31.3	1.14	12	0
JTRM 806	Jarit	7.9	30.2	1.51	9	-2
Stirling	Yates	7.8	58.6	1.8	7	1

Table 9. Region 2 Spring and summer transition – central Australia - *Cunnamulla 2003*

Variety	Supplier	SSC (%)	Yield (kg/ha)	Fruit wt (kg)	Size grade	Maturity
RML 0036	Syngenta	13.6	27.0	0.8	18	-4
Esteem (RML 7923)	Syngenta	13.3	30.4	0.9	16	-4
Kooba F1	Lefroy Valley	11.7	42.5	1.1	13	-2
JTRM 819	Jarit	11.4	57.2	1.1	12	-3
RML 0034	Syngenta	11.4	46.1	1.2	12	-3
LX2481	SPS	11.3	29.8	1.2	11	-1
437-2	SPS	11.0	47.9	1.2	11	0
Eastern Shipper type	Syngenta	10.8	52.7	1.8	7	-4
RML 0031	Syngenta	10.8	54.0	0.8	16	1
JTRM 820	Jarit	10.7	48.5	1.1	12	-4
611-0	SPS	10.5	65.3	1.3	10	-2
JTRM 815	Jarit	10.4	62.7	2.1	6	-4
Arpege	Rijk Zwaan	10.4	46.6	1.2	12	-3
YRM 3621	Yates	10.3	56.1	1.6	8	-2
994002	Henderson's	10.3	32.0	1.3	10	-1
Athena	Syngenta	10.2	49.0	1.6	8	-4
Hotshot	Syngenta	10.1	67.3	1.7	8	-4
Aphrodite (RML 8793)	Syngenta	10.1	51.1	2.0	6	-4
Proteo	Syngenta	10.0	66.8	1.5	9	-2
CLX 2777	Lefroy Valley	10.0	47.9	1.2	11	-1
Gold Express (RML 7930)	Syngenta	10.0	56.6	1.1	12	-2
440-2	SPS	9.9	54.2	1.4	10	-2
Dubloon	Syngenta	9.9	48.7	1.2	11	0
Vicar (Galia type)	Syngenta	9.9	50.7	0.9	15	1
Eastern Star type	Syngenta	9.8	76.2	1.9	7	-3
YRM 3628	Yates	9.8	60.8	1.4	10	-3
Aitana	Rijk Zwaan	9.7	56.9	1.0	13	-2
586-1	SPS	9.7	46.6	1.3	10	-1
5168	SPS	9.5	45.5	1.0	13	0
Galileo (Galia type)	Syngenta	9.4	39.9	1.0	14	1
Tobbia	Rijk Zwaan	9.3	69.0	1.1	13	0
441-2	SPS	9.3	69.2	2.3	6	-4
RML 8793 (Eastern Ship.)	Syngenta	9.3	79.7	2.3	6	-4
Ocotillo	Syngenta	9.1	49.1	1.4	9	0
Eldorado	Syngenta	9.1	66.6	1.9	7	-3
JTRM 806	Jarit	9.0	64.6	1.1	13	-1
438-2	SPS	8.9	41.6	1.2	11	0
JTHD 902	Jarit	8.8	48.6	1.6	8	0
MEL 1774	Lefroy Valley	8.6	58.3	1.5	9	-1
JTRM 827	Jarit	8.6	79.3	2.3	6	-1

Colusa	Lefroy Valley	8.5	48.7	1.6	8	-1
RM 1029	Syngenta	8.5	64.4	2.6	5	-1
JTHD 901	Jarit	8.4	77.1	2.2	6	1
849	SPS	8.3	57.4	1.6	8	1
JTRM 826	Jarit	8.2	72.5	2.4	5	-1
500-9	SPS	8.2	56.0	1.2	11	0
LUXO	Lefroy Valley	7.8	30.0	1.2	11	1
JTHD 904	Jarit	7.7	49.5	1.7	8	1
JTHD 818	Jarit	7.6	68.0	1.5	9	1

Table 10. Region 2 Spring and summer transition – central Australia - *Bourke 2004*

Variety	Supplier	SSC (%)	Yield (kg/ha)	Fruit wt (kg)	Size grade	Maturity	Firmness (kg/cm2)
516-8	SPS	12.2	40.9	1.5	9	4	6.4
RML 0036	Syngenta	11.7	29.6	1.0	13	0	3.1
437-2	SPS	11.5	54.8	1.9	7	0	3.6
586-1	SPS	11.2	57.5	2.3	6	4	5.7
Solreal	Syngenta	11.0	26.6	1.5	9	-2	2.0
RML 0034	Syngenta	10.8	24.9	1.4	10	-2	2.6
1149	Syngenta	10.8	37.3	1.3	10	0	3.3
Dubloon	Syngenta	10.6	38.3	1.6	8	0	2.6
svr 1460-4099	Seminis	10.4	44.9	1.7	8	0	3.6
1194	Syngenta	10.3	23.1	1.3	10	-4	2.3
jtrm 819	Jarit	10.2	32.5	1.3	10	0	3.2
Esteem	Syngenta	10.2	35.6	1.3	10	-2	3.4
Pablo	SPS	10.1	52.0	1.9	7	-2	3.6
Durack	Yates/SPS	10.0	39.0	1.8	7	-2	3.0
Sweetheart	Jarit	9.9	55.5	3.3	4	0	4.7
svr 1461-1013	Seminis	9.8	51.5	2.3	6	0	3.3
Gold Express	Syngenta	9.0	36.9	1.5	9	0	3.2
302-3	SPS	8.6	29.2	1.8	7	0	5.4

Table 11. Region 3 Summer and autumn transition southern Victoria *Mildura 2003/4*

Variety	Supplier	SSC (%)	Yield (kg/ha)	Fruit wt (kg)	Size grade	Firmness (kg/cm2)
svr 1460-4099	Seminis	14.3	25.7	0.9	16	5.9
Proteo	Syngenta	13.4	54.9	1.4	9	3.6
Dubloon	Syngenta	13.2	0.0	1.7	8	3.3
RML 0036	Syngenta	13.0	39.1	0.8	17	6.0
Hi-Line		12.3	48.0	1.5	9	4.6
1194	Syngenta	12.0	35.5	1.2	11	3.4
RML 0034	Syngenta	11.4	53.0	1.3	10	3.0
JTRM 819	Jarit	11.4	38.1	1.2	11	3.0
Esteem	Syngenta	10.8	26.3	1.0	14	3.4
Northern Sky	Syngenta	10.6	0.0	2.1	6	4.2
Frontier		10.5	0.0	1.7	8	2.8
Mel 9409	Lefroy Valley	10.1	34.9	1.2	11	7.4
Sweetheart	Jarit	10.0	31.6	1.8	7	2.6
536-3	SPS	9.9	53.1	2.2	6	5.7
Portola F1	Lefroy Valley	9.7	40.2	1.8	7	5.6

Table 12. Region 3 Summer and autumn transition southern Victoria *Irymple 2005*

Variety	Supplier	SSC (%)	Yield (kg/ha)	Fruit wt (kg)	Size grade	Firmness (kg/cm2)
Pegaso	Claus	15.8	20.6	1.6	8	5.3
ACX 2076	Abbot & Cobb	15.6		1.8	7	5.5
RM 1248	Syngenta	15.5	13.4	1.7	8	9.0
ACX 9201	Abbot & Cobb	15.4	65.3	2.1	6	8.7
SPS HD 1422	SPS	14.8	40.3	1.7	8	5.1
RM 1233	Syngenta	14.5	29.3	0.9	15	5.9
SPS HD 581-4	SPS	14.5	32.9	1.2	11	4.0
Chantel	Syngenta	14.2	26.4	1.6	8	8.6
ACX 2078	Abbot & Cobb	14.2	34.3	2.6	5	8.8
JTRM 843	Jarit Seeds	14.1	33.0	1.2	11	7.3
Southern Cross	Syngenta	14.1	27.7	1.6	8	6.9
RM 1217	Syngenta	13.9	17.8	0.8	17	7.0
RM 1146	Syngenta	13.9	25.4	1.0	13	6.5
RM 1253	Syngenta	13.6	23.9	1.4	9	4.7
Solid Gold	Syngenta	13.6	41.4	2.5	5	8.6
RM 1245	Syngenta	13.6	33.6	1.5	9	6.7
SPS 5801	SPS	13.4	73.5	2.6	5	8.7
Delicious	Syngenta	13.4	32.0	1.2	11	10.3
RM 1250	Syngenta	13.3	39.9	0.7	19	3.6
Ultra Sweet Daltona	Terranova	13.2	28.3	1.6	8	7.4
SVR 1460-4099	Seminis	13.2	19.0	0.9	16	7.9
RM 1246	Syngenta	13.2	48.0	1.9	7	8.1
PX 6391-3108	Seminis	13.0	27.7	1.4	9	7.5
Comet	SPS	12.8	38.5	1.6	8	6.5
SPS 3023	SPS	12.7	28.3	1.5	9	5.3
RM 1260	Syngenta	12.7	46.9	2.8	5	7.7
RM 1165	Syngenta	12.6	24.2	1.8	7	7.5
Dubloon	Syngenta	12.6	73.1	1.8	7	6.2
SPS 856-3	SPS	12.3	19.9	1.2	11	5.9
XP 0439-1649	Seminis	12.1	29.4	0.8	17	9.0
RM 1249	Syngenta	11.9	62.9	1.3	10	5.3
RM 1261	S&G Syngenta	11.5	32.7	2.0	6	10.7
JTRM 851	Jarit Seeds	11.3	58.2	1.6	8	4.8
Sweetheart	Jarit Seeds	10.6	33.8	2.5	5	6.5
Isabella	Seminis	10.4	23.2	0.8	16	10.9
Sienna	Terranova	10.3	26.0	1.7	8	4.9
JTRM 847	Jarit Seeds	10.1	24.0	1.4	10	4.7

4. Source-sink manipulation

Introduction

In Australia consumer dissatisfaction rates of up to 60 % have been reported for orange flesh rockmelon (Cucumis melo L. reticulatus group) (herein referred to as melon) (Australian Melon Association, 2003).

Biomass and carbohydrate content of fruit can be manipulated by agronomic practices that increase assimilate partitioning to fruit in a number of crops e.g., hand and chemical thinning of fruits is common in the apple (Basak, 2002), citrus (Stover et al., 2001), and stone fruit (Byers et al., 2003) industries to increase fruit size and SSC. Plant growth regulator applications can also be used to improve partitioning to fruit (Looney, 1997) and pollination scheduling can be used to alter the number of fruit set, and the source to sink ratio (e.g. in apple, Benedek and Nyeki, 1996). Therefore a number of manipulation options are available, although in all examples the timing of treatments in relation to the development of the fruit is critical.

Similar treatments should be possible for the manipulation of rockmelon fruit yield and quality, however, the literature based on source-sink manipulation of rockmelon is sparse, with more focus on the effect on fruit biomass than carbohydrate content.

Melon fruit show a typical sigmoidal growth curve (McGlasson and Pratt, 1963), with four separate phases to fruit development (Higashi and Ezura, 1999): (1) Ovary development; (2) Cell division (this phase being a primary determinant of fruit size in terms of sensitivity to temperature); (3) Cell expansion; and (4) Sugar accumulation. Fruit fresh weight reaches a plateau, and may decline, during the last two weeks of development (Chrost and Schmitz, 1997), while total sugar accumulation continues until fruit abscission (Lester et al., 2001).

Total sugar accumulation throughout the life of a melon fruit may be either linear (Lester and Dunlap, 1985), or have a distinct increase in the final stages of development (Miccolis and Saltveit, 1991; Chrost and Schmitz, 1997). Broadly, sugar accumulation in a fruit can be influenced by source availability and or competing sink activity. However, a change in source availability from early plant development may result in a change in the number of fruit set and in biomass per fruit, with similar sugar content (e.g. Hubbard et al. 1990). Thus, when Eichen et al. (1994) used floating row covers to exclude bees from field grown cantaloupe plants, delaying pollination by 0, 6, or 12 days, the source to sink balance was manipulated.

Delayed pollination was reported to generally result in a greater total fruit biomass and greater number of fruit per plant, with no effect on fruit SSC. A

change in source availability late in fruit development may, therefore, be more likely to impact fruit SSC. Melon fruit are described as 'dominant' sinks, relative to vegetative growth (El- Keblawy and Lovett-Doust 1996).

When fruit are removed from a melon plant, the plant will re-invest the available photosynthate into the remaining fruit, or into vegetative growth (e.g. Valantin et al., 1998), although photosynthetic rate may decrease through a negative feedback loop (product inhibition). Removal of competing sinks early in fruit development is likely to lead to the setting of subsequently more fruit, while removal in later fruit development is likely to result in increased fruit SSC and weight, but decreased overall yield.

Plant growth regulators can also be used to influence source-sink balance in melons. Application of ethrel (Sidhu et al. 1982) or the synthetic cytokinin 1-(2-chloro-4- pyridyl)-3-phenlurea (CPPU) (Hayata et al. 2001; 2002) to newly pollinated ovaries has been reported to increase fruit set and yield per plant, but to have no effect on fruit SSC. However, application of paclobutrazol to plants at a later stage in fruit development inhibited vegetative growth and resulted in increased fruit SSC, but not fruit weight (Nerson et al. 1989).

A range of techniques for manipulating the source-sink ratio and assimilate partitioning to the melon fruit exist. This study examines these manipulations with a focus on the effect on fruit SSC.

Methods and materials

Plant material and culture. Experiments were conducted on three commercial farms, located in Kununurra, Western Australia (Lat –15^{o} 46' Lon 128^{o} 44'), in Bourke, New South Wales (Lat – 4 30^{o} 2' Lon 145^{o} 57'), and in Kabra, Queensland (Lat –23^{o} 28' Lon 150o 23'), and in a glasshouse at Central Queensland University, Rockhampton, Queensland (Lat –23^{o} 22' Lon 150^{o} 32'). In Kununurra, seeds were directly sown singly into uncovered beds 1.8 m apart, at 3 to 4 cm depth and 40 or 50 cm spacing. Fertiliser was delivered as a pre-plant base comprising 44 kg N ha-1, 60 kg P ha-1, 49 kg K ha-1, 20 kg S ha-1, 56 kg Ca ha-1 and 18 kg Zn ha-1. Furrow irrigation was delivered for 6 h at germination, 6 h at first male flower production, and for 6 h late in fruit development.

In Kabra, seedlings were transplanted approximately 14 days after sowing 60 cm apart into plastic covered beds 2.0 m apart. Pre-plant base and fertigated nutrition totalled 88 kg N ha-1, 167 kg P ha-1, 56 kg K ha-1, 63 kg S ha-1 and 20 kg Ca ha-1. A surface trickle line delivered irrigation at seedling transplant, and again after 14 days, for 1.5 h per day until early to mid fruit development, and for 2 h per day for the remainder of the crop. At Bourke, single seedlings were transplanted at 40 cm spacing into rows at 2 m centres, served by a surface

trickle line. Beds were covered with plastic mulch containing a surface trickle line. Pre-plant base and fertigated nutrition totalled 50 kg N ha-1, 17 kg P ha-1, 113 kg K ha-1 and 15 kg Ca ha-1. Irrigation was subjectively delivered to meet the crop requirements.

For glasshouse propagation, 8.3 L plastic draining pots were lined with shade cloth and filled with steam-sterilised sand. Two seeds (cv. Hot Shot) were sown at 15 mm depth, per pot. Full strength hydroponic solution (elemental concentration - ppm: N 215, P 37, K 218, Ca 152, S 54, Mg 42, Fe 4.08, Mn 0.96, Zn 0.48, Cu 0.36, B 0.036, and Mo 0.012) (N: P: K ratio of 5.8: 1: 5.9) was delivered to pots via automated flooding benches (100 mm depth, flooding daily for 1 h, 10 to 15 pots per bench), with re-circulated nutrient solution replaced every three to four weeks. Solution pH was adjusted weekly to 6.5 using 1M KOH or 1M H2SO4.

Measurements. Unless otherwise stated, fruit were harvested when they abscised ('slipped') from the vine, fruit number and fresh weight (and dry weight for some experiments), were recorded and the SSC of fruit mesocarp tissue determined.

For SSC assessment, a 22 mm diameter core of mesocarp tissue was extracted from an equatorial position of the fruit and divided into 1 cm slices, starting from the outer side. Each 1 cm slice was pressed using a hand operated garlic press, and the SSC of the resulting juice determined using on a Bellingham and Stanley RFM 320 digital refractometer. 2.3.

Phenology trial. From a field of plants (cv. Malibu) seeded in March 02 at the Kabra farm, eight plants were selected at random from a single row at 7 d intervals, to monitor biomass partitioning and fruit SSC. Plants were partitioned into organs and weighed (following drying at 70 ^{o}C for up to 5 days). In addition, 30 fruit selected at random from adjacent rows were harvested each week for SSC assessment. For three fruit, a tissue sample was diced into approximately 0.5 cm sided cubes and freeze dried for 48 h in a Virtis Sentry freeze dryer for sugar analysis.

Each sample was ground into a known amount of 80 % ethanol (approximately 10 ml), agitated for 2 min, allowed to extract for 30 min in a 65^{o}C water bath, and then centrifuged for 10 min. A subsample of the supernatant was stored for HPLC determination of sucrose, glucose and fructose, using a Waters carbohydrate column and a refractive index detector.

Sink manipulation – fruit thinning. Two field trials were conducted at each of the Kabra and Kununurra farms to examine the effect of fruit thinning, implemented at different times before fruit maturation, on the sugar content and yield of the remaining fruit.

Treatments for each trial were arranged in a randomised complete block design (RCBD). During the 2000 season in Kununurra, fruit were removed either 5 or 10 d before harvest (DBH) from cv. Hotshot vines to leave one fruit per plant. Each treatment was imposed over a 10 m portion of a row, and replicated three times. An identical treatment was also imposed on two successive plantings (2001 and 2002) of cultivar Malibu at the Kabra field site, except that in the 2001 experiment, plants were thinned at 4, 11, 18, 25 and 32 d before harvest, while in the 2002 planting, thinning was implemented at 12, 19 and 26 d before harvest. Each treatment was imposed on 10 plots, with each plot consisting of six and four plant positions (two plants per planting hole) in 2001 and 2002, respectively.

A fourth field experiment was established in 2002 on the Kununurra farm using cultivar Hotshot. Two levels of planting density (25 and 50 cm seed spacing, or 11,111 and 22,222 plants ha-1) were combined factorially with three fruit removal treatments (control, thinning of fruit to one per plant, and thinning to leave two fruit per plant) implemented 21 DBH. Treatments were replicated three times, with each replicate consisting of a 2 m portion of a planting row.

Fruit thinning treatments were also imposed on cv. Hotshot grown under glasshouse conditions (May to August 2001). Plants were hand pollinated to set one fruit on each of 17 plants and two fruits on each of 15 plants. Four plants were left unpollinated. At approximately 31 days after pollination (21 DBH), one fruit was removed from seven of the plants bearing two fruit, and eight plants that had been set with one fruit were thinned to no fruit. Treatments were completely randomised.

Photosynthetic rate of a single leaf, eight to ten node positions from the apex of the main branch, was measured for each plant, seven days after fruit thinning (14 DBH). Measurements were made from 12:00 to 14:30 on a cloudless day using an ADC Limited LCA-4 infrared gas analyser. At harvest, root tissue was recovered as well as shoot and fruit organs.

Source manipulation – leaf removal. The effect of removal of photosynthetic source organs on yield and sugar content of fruit of cv. Hotshot was determined in a trial conducted in Kununurra during 2000. The following five treatments were implemented at early to mid fruit development and at late fruit development (21 and 8 DBH, respectively).

Source organs were removed basipetal relative to the branch apex: (i) 25% of leaves were removed from each branch; (ii) 50% of leaves were removed from each branch; (iii) 25% of each branch was removed; (iv) 50% of each branch was removed; and (v) no treatment (control). Each treatment comprised a 5 m plot within a row and the ten treatments were randomly allocated within a 50 m portion of a row. The treatments were replicated four times throughout the planting as a RCBD.

Chemical inhibition of vegetative growth 'NBX', (a chemical inhibitor of vegetative growth). According to the manufacturer (Stoller Australia), NBX inhibits the movement of auxin from the growing tips, which in turn limits assimilate movement 6 toward the growing tips, allowing partitioning to other sink organs. Active ingredients are reported as B (10 % w/v), Mo (0.007 % w/v), polyamine complexing agents and seaweed derived cytokinin.

NBX was applied via a backpack sprayer at an approximate rate of 3 L/ha (recommended rate 2–4 L/ha) in one glasshouse and three field trials. For the three field trials, treatment plots (arranged in a RCBD) were surrounded by 2 m buffer zones. At Bourke (April 2001), NBX was applied to a 5 m portion of a row of cv. Dubloon, with four replicates, at 15 DBH. At Kabra (September 2001), NBX was applied to 5 m plots of cv. Eastern Star, with eight replicates, at 3 and 7 DBH.

At Kununurra (September 2002), NBX was applied to a 2 m portion of a row of cv. Hotshot, with six replicates, at 10 DBH. In the glasshouse trial (August to November 2001), NBX was applied 7 DBH to eight cv. Hotshot plants which had been set with one fruit per plant. Treatment and control plants were completely randomised.

Pollination scheduling. The effect of delaying fruit set on fruit SSC and weight was examined in two glasshouse experiments (December 01 to March 02, and June to October 02, cv. Hotshot) and one field experiment (cv. Sahara, at Kabra from August to November 02). In the first glasshouse experiment, one fruit was set close to the centre ('crown') of each of 13 plants. Twenty one days after this event, eight plants that had been denied fruit set ('delayed plants') were pollinated to set one fruit per plant. In the second experiment, two plantings (of 29 and 20 pots) were staggered by 20 days.

When the later planting began to produce female flowers, one fruit per plant was set for both groups of plants. In the field trial, white Marix thermal net cover (VP Trade Goods, Brisbane; 20 % shade) was used to cover plants within three treatments: (i) control plants (with covers in place but with open sides); (ii) first or 'crown' fruit set (sides of covers were closed after first fruit set); (iii) pollination delayed by 14 days (sides of net covers closed until 14 days after treatment ii, then opened for 5 days). Each treatment comprised ten plants per plot, with four replicate plots in a RCBD.

Statistical analyses. The SAS System and SPSS 11.5 for Windows were used for ANOVA statistical testing. Means were separated by either the least significant difference or Dunnett's test, at $P<0.05$. Microsoft Excel was used for regression analysis.

Results and Discussion

Phenology. In a field trial involving cv. Malibu, the crop cycle was completed in 11 weeks (79 d) (Fig. 1). The first noticeable flower count was at 23 d after transplant, and flower number peaked at 37 d. Fruit became the dominant organ (by mass) at 51 d (28 DBH). The biomass of main branch stems was fairly static from this point, while main leaf and lateral stem biomass increased, peaking 7 to 14 DBH. Lateral leaves contributed the most to total vegetative plant biomass, and had a biomass comparable to that of fruit. At harvest, fruit accounted for 51 % of plant above ground biomass (dry weight basis).

Fruit development (pollination to fruit abscission) occurred over a period of approximately 42 days. Total fruit weight (DW and FW) rapidly increased until three weeks before harvest (8 weeks after transplanting), and then plateaued, but fruit SSC continued to increase (Fig. 1), consistent with the reports of Hubbard et al. (1989), Miccolis and Saltviet (1991), and Chrost and Schmitz (1997). The SSC of inner, middle and outer mesocarp tissue was similar during early fruit development, increasing in all tissues from 4 to 6 % SSC within the first 4 weeks of development. In later development, middle and inner tissue accumulated sugar at a greater rate, with middle tissue SSC increasing by 2 SSC units, and inner tissue increasing by 4 SSC units during the last three weeks. The total amount of soluble sugar per fruit increased linearly during fruit development, with the mature fruit containing approximately 100 g sugar per 1000 g FW fruit.

Glucose and fructose concentrations were always similar, and increased from 160 to 200 mg g DW –1 during the initial three weeks of fruit development, but then decreased to about 150 mg g DW-1 at fruit abscission. Sucrose concentration was very low during early fruit development (between 0 and 10 mg g DW-1), but increased dramatically within the last three weeks to equal hexose concentration (Fig. 1). This result is consistent with that of Lester and Dunlap (1985), who also noted that sucrose content continued to increase at the expense of the monosaccharides following fruit harvest.

The effect of a manipulation of the source or sink is expected to be specific to the developmental stage of the fruit and the plant. Thus, for example, an increase in carbohydrate availability to fruit seven weeks before harvest might allow more cell division, resulting in larger fruit, but with no increase in fruit SSC. In contrast, increasing carbohydrate availability close to harvest, after fruit had passed their cell division and expansion phases, should result in increased sugar storage.

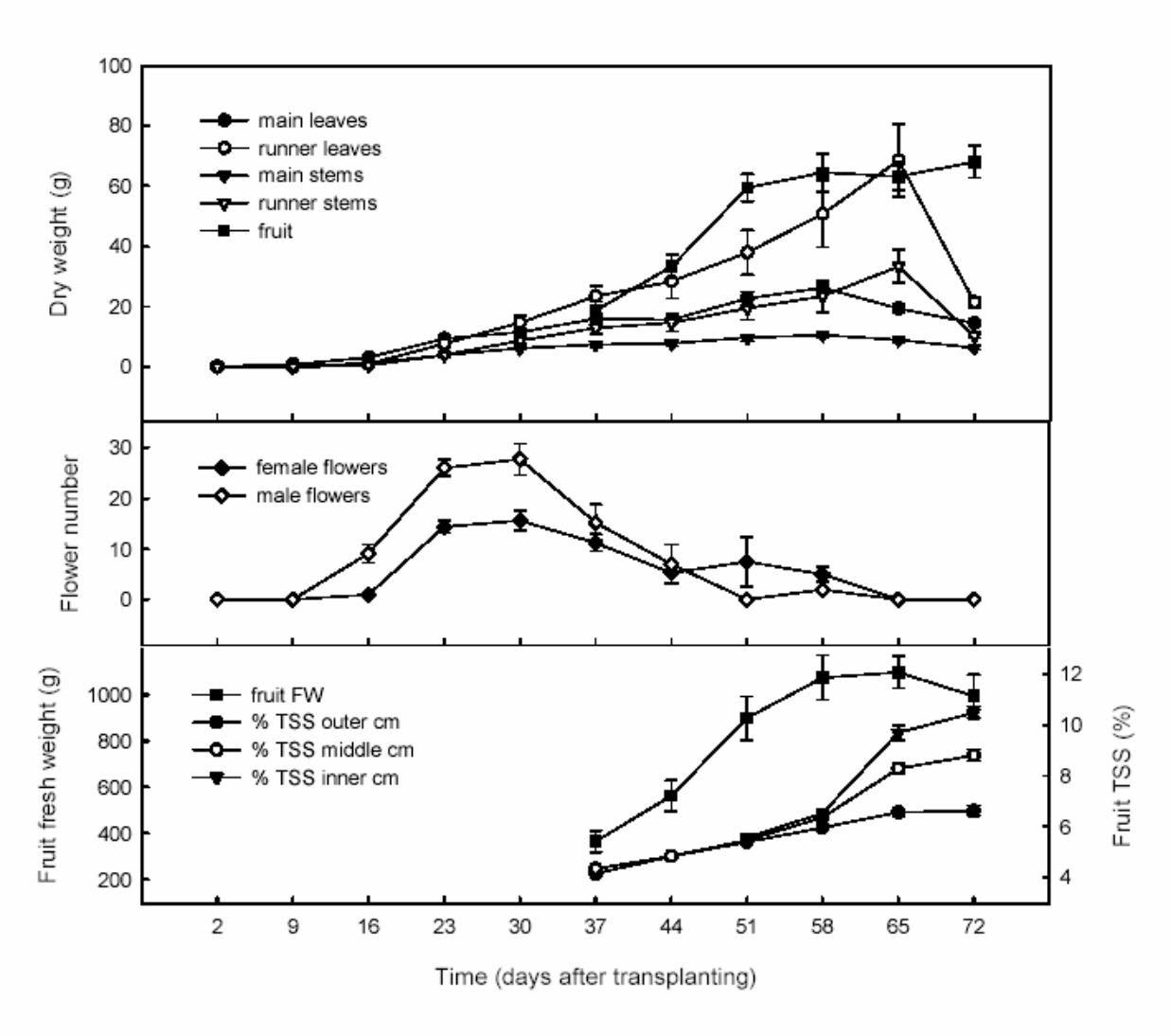


Figure 1. Phenology of cv. Malibu rockmelon plants (*Cucumis melo* L) grown on a commercial farm at Kabra Queensland from 30 March until 15 June 2002. For dry weight and flower number, each data point represents the mean and se for eight replicate plants. For TSS and fruit fresh weight, each data point represents the mean and se for 30 replicate fruit.

Patterns of partitioning. In control (pooled glasshouse grown) plants, a positive correlation (r2 = 0.94) was noted between leaf weight ratio and fruit fresh weight per plant, and a similar but negative relationship (r2 = 0.88) existed between harvest index and fruit fresh weight (Fig. 2). The correlation between either leaf weight ratio or harvest index and SSC was poor, although as fruit development time advanced, leaf weight ratio decreased and harvest index increased. Thus, in non-manipulated plants, source availability was linked to fruit biomass, rather than fruit sweetness.

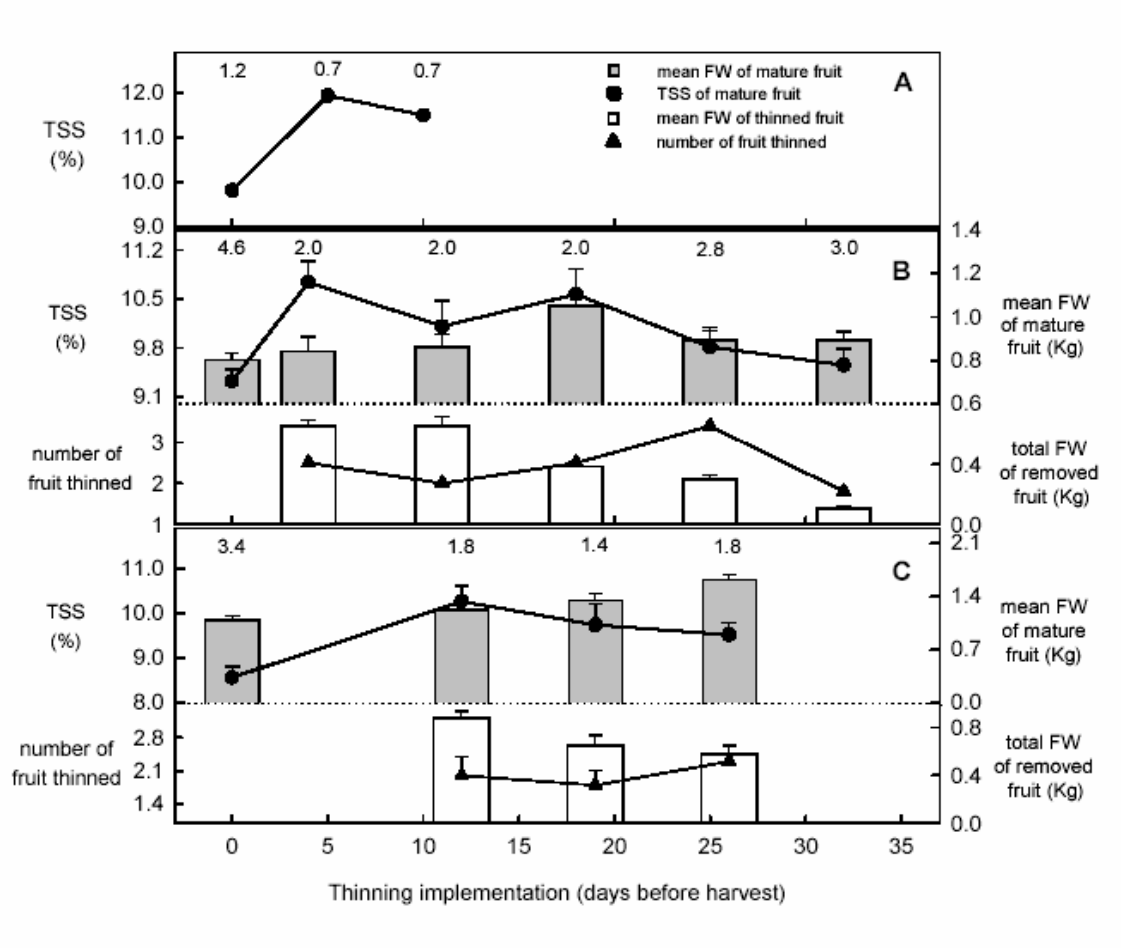


Figure 2. The effect of the timing of fruit removal (leaving one fruit per plant) on the fresh weight and TSS of remaining fruit. Data are from field trials at (A) Kununurra 2000 with cv. Hotshot, (B) Kabra 2001 with cv. Malibu, and (C) Kabra 2002 with cv. Malibu. Data points are displayed as mean values with se. Numbers above bars indicate the number of fruit harvested at maturity per planting replicate. ANOVA for mature fruit TSS and fresh weight for the three locations were significant (P = < 0.001). LSD0.05 values for (A) 0.3 %; (B) TSS 0.8 %, FW 0.1 kg; (C) TSS 0.9 %, FW 0.2 kg.

Total plant biomass was similar for plants with one or two fruits and plants that never set fruit (average 65 g DW, glasshouse trial, Fig. 3), however biomass was partitioned differently. For plants with fruit, about 80 % of total biomass was apportioned to fruit, and only 5% was apportioned to lateral branch stems and leaves. In contrast, plants that were denied fruit set invested resources into lateral branch production, such that at harvest 50 % of total plant biomass was in the form of branches and flowers (Fig. 3).

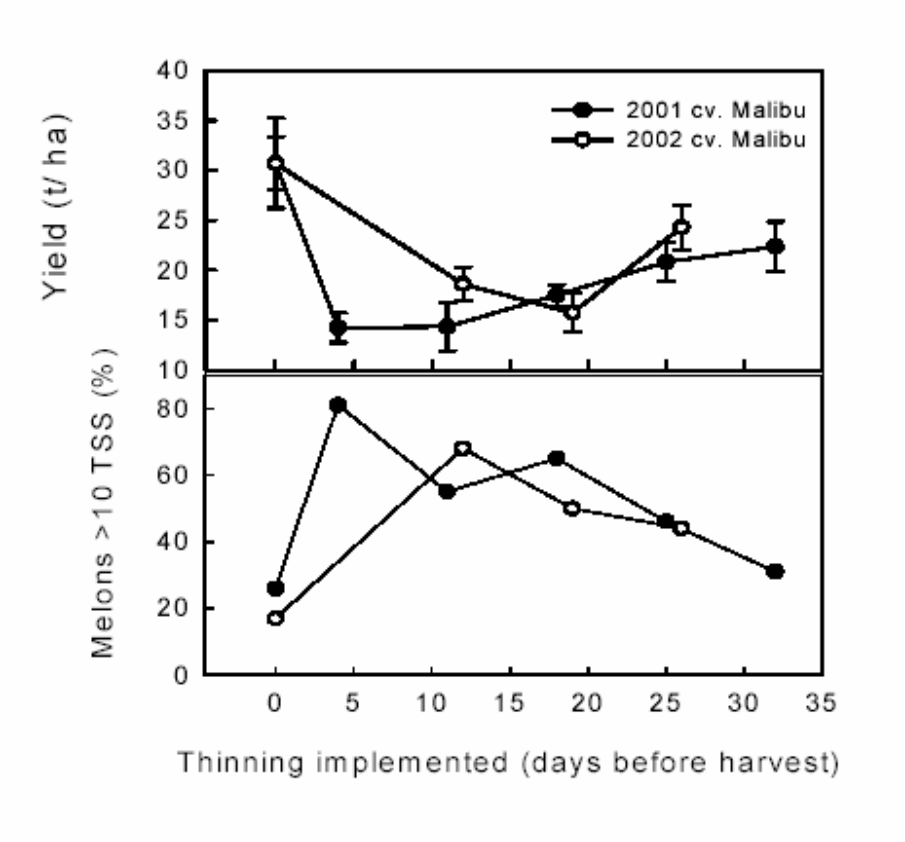


Figure 3. Yield (t/ ha) and the percentage of melons with flesh TSS ≥10 %, from thinning treatments leaving one fruit per plant, for two plantings (2001 and 2002) of cv. Malibu rockmelons (*Cucumis melo* L) grown on a commercial farm at Kabra Queensland. Data are common to Fig 2. Yield values are presented as means and se. ANOVA analysis was significant for yield ($p<0.01$); LSD0.05 between dates were 6.0 (2001) and 7.5 t/ha (2002).

For plants in which all fruit were removed 21 DBH, resources were again invested into branch production, such that at maturity 38 % of total biomass was allocated to branches and flowers (Fig. 3). Thus, at fruit maturity, leaf weight ratio was two to three fold higher in plants with no fruit than in plants bearing fruit, and the 8 ratio was also higher for plants denied fruit set compared to plants which were thinned of all fruit (45 vs. 39 %, respectively) (Table 1). Harvest index was similar for plants bearing one and plants bearing two fruit, which was greater than plants that were thinned to one fruit (table 1).

Source availability is determined by leaf area and photosynthetic rate per unit area. Photosynthetic rate is expected to vary in response to the source – sink (mass) ratio through a product inhibition response. In glasshouse plants in which fruit were removed 21 DBH, photosynthetic rate (taken at 14 DBH) was not significantly different between plants bearing one or two fruits (average 9.9 μmol CO2 m-2 s-1), but was markedly lower in plants thinned of all fruit (thinned to no

fruit, 3.6 µmol CO2 m- 2 s-1) (Table 1). In plants that were not allowed to set fruit, the photosynthetic rate was lower again, at 1.5 µmol CO2 m-2 s-1.

Table 1. The effect of thinning fruit at 21 dbh from plants to leave one and two fruit per plant for *Cucumis melo* L cv. Hotshot. Plants were grown at 25 cm and 50 cm seed spacing, on a commercial farm in Kununurra WA in 2002. Mean values for fruit TSS, fruit fresh weight and yield are reported. LSD is reported for the significant ANOVA result for TSS. Note. There was no interaction between thinning and spacing; for thinning P = 0.045 on TSS, P = 0.152 on FW, P = 0.78 for yield; for spacing P = 0.96 on TSS, P = 0.54 on FW, P = 0.23 on yield.

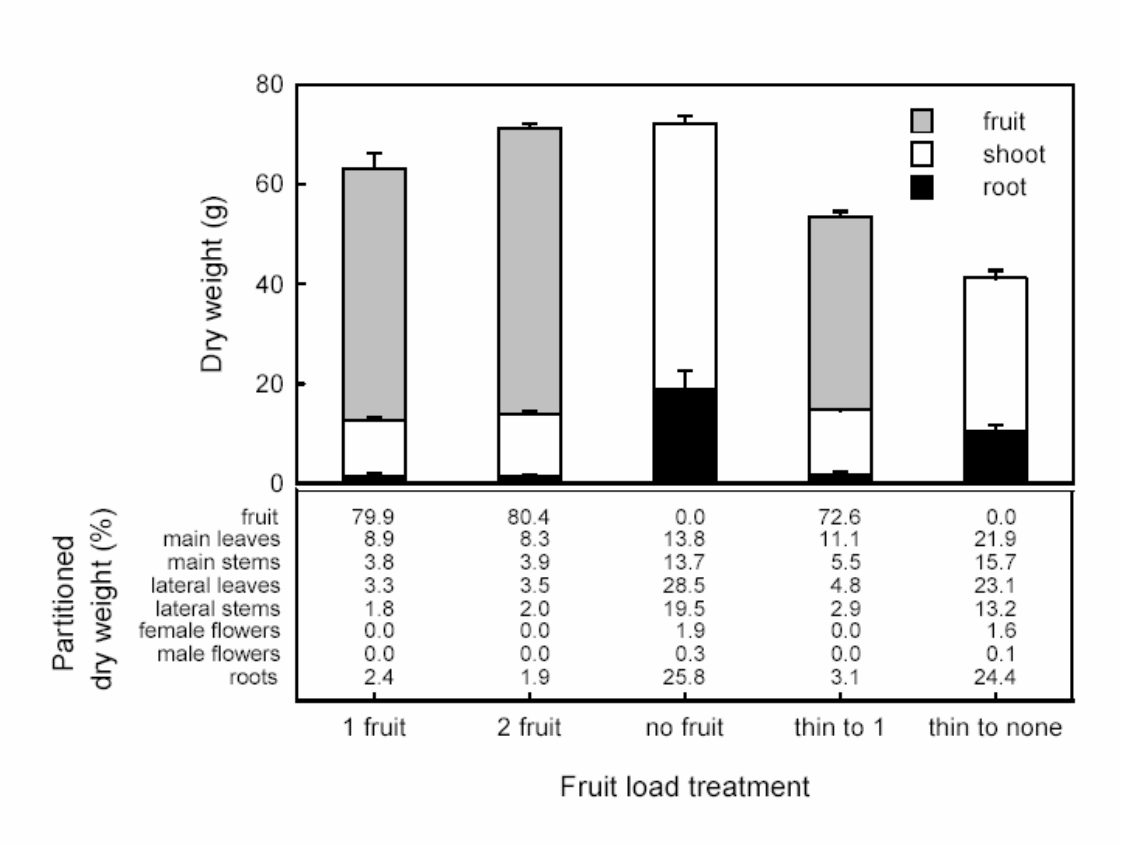
	50 cm spacing			25 cm spacing			
	control	2 fruit	1 fruit	control	2 fruit	1 fruit	LSD
TSS (%)	8.6	9.3	9.9	9.2	9.0	9.6	0.9
FW (g)	1568	1516	1692	1608	1579	1676	ns
yield (t ha^{-1})	31.4	30.3	28.5	36.9	31.8	35.4	ns

These results are consistent with those of Valantin et al. (1998) who recorded a maximum photosynthetic rate of 15 µmol CO2 m-2 s-1 in melon leaves, with no variation in plants thinned of fruit load, and proposed that the family Cucurbitaceae is characterised by a loose connection between sink demand and specific photosynthetic rate. Marcelis (1991) also noted that leaf net photosynthesis was only reduced in cucumber plants when all fruit were removed. Leaf photosynthetic rate is therefore not expected to decline with time from fruit thinning, although leaf area will increase, driving an increase in plant photosynthetic capacity.

On balance, however, thinning of fruit increased the availability of assimilate to remaining fruit, and fruit of plants set with one fruit and plants thinned to one fruit possessed higher SSC than that of plants bearing two fruit (by 130 and 125 %, respectively; Table 1). Mean fruit FW was also greater for plants which were set with a single fruit compared to plants thinned to one fruit or plants with two fruit (486, 395 and 312 g, respectively), although total FW yield per plant was significantly greater for two fruit plants (625 vs. 486 g for plants bearing two and one fruit, respectively).

Sink manipulation - Fruit thinning. Thinning close to harvest (4 to 12 DBH) was more effective in increasing the SSC of fruit (typical increase of 2 % SSC, e.g. from 9.8 to 12 % in the Kununurra trial), than earlier thinning events (Fig. 4), but also had the most detrimental impact on fruit yield per plant. SSC increased by 15, 22 and 22 % in the Kabra 01 (thinned 4 DBH), Kununurra (5 DBH) and Kabra 02 (12 DBH) trials, respectively (Fig. 5A, B, C), in which fruit number per planting hole was reduced by 42%, 56% and 47%, respectively. These fruit had passed their cell expansion phase, so fruit did not increase in size, and assimilate was partitioned to sugar storage.

Figure 4. Fruit, shoot and root dry weight partitions (mean values and associated se), the percentage of dry matter partitioned within plants, for glasshouse grown cv. Hotshot rockmelons (*Cucumis melo* L) sampled at the time of fruit maturation. Data common with Table 2.



Thinning during the cell expansion phase (14 to 21 DBH) resulted in larger fruit, but had less effect on fruit SSC (Fig. 5). For the 01 Kabra cultivar Malibu population, mean fruit fresh weight was greater for treatments imposed at or before 18 DBH (1050 cf. 800 g for control), while in the 02 trial fruit weight was greater for treatments imposed at or before 26 DBH (1600, cf. 1100 g for control).

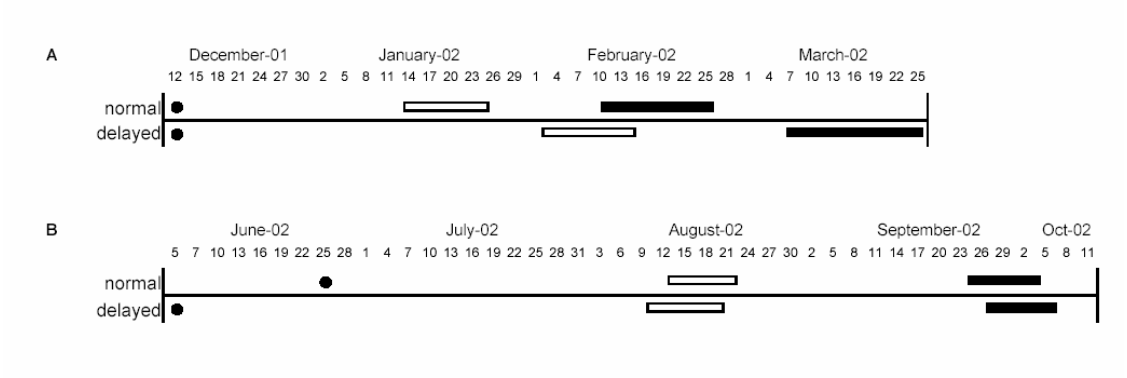
Similarly, in a glasshouse trial (Table 1), thinning was implemented 21 DBH. Plants that were initially set with one fruit, or thinned to one fruit, bore fruit with SSC higher than fruit from plants bearing two fruit. Single fruit from the thinned treatment were also larger (395 g FW) than the two fruit treatment (312 g FW), although not as large as one fruit 9 treatment (486 g FW). Thus, more assimilate was made available to the remaining fruit during the cell expansion and sugar accumulation phases.

Thinning at even earlier stages allowed for more vegetative growth, enabling plants to produce female flowers and set additional fruit (e.g. where fruit were thinned 32 DBH, leaving 2 fruit per plant hole, 3 fruit were harvested; Fig. 4B). Competition for assimilate between these fruit would result in lower SSC, relative

to the treatment of thinning close to fruit maturity. Thus fruit thinning in the last weeks of fruit development increased the proportion of melons in a population that exceeded a quality control standard of 10% SSC (from approximately 20 % in the control population to 80 % and 70 % in the Kabra 01 (4 DBH) and Kabra 02 (12 DBH) trials, respectively; Fig. 5). However, thinning treatment reduced harvestable yield.

Yield was reduced from 31 t ha-1 to between 15 and 20 t ha-1, increasing to between 23 to 25 t ha-1 with increasing time before harvest for thinning implementation (Fig. 5). The converse of this observation is seen in the record of the weight of fruit removed in thinning operations (e.g. Fig. 4B, lower panel).

Figure 5. Time line of events for two successive glasshouse plantings of cv. Hotshot *Cucumis melo* L. examining the effect of setting one fruit per plant for a group of plants delayed of pollination (delayed), and for a group of plants during normal first wave flowering (normal). Seeding date (•), pollination (□) and plant harvest (■) events are shown. Experiment A treatments were seeded on the same day, while experiment B treatment plants were seeded 20 days apart.



Source manipulation - Removing leaves: Manipulating the source, by reducing or impeding branch growth, has been examined as a method of controlling flower production, but the effects on fruit yield or SSC were either unsuccessful or not reported (Rane, 1900; Lloyd, 1920; Wolf and Hartman, 1942). In the one published report on the effect of source removal on fruit SSC, Hubbard et al. (1990) removed 50 % of plant leaves 28 DBH, and noted a significant reduction in fruit SSC, although neither fruit weight nor yield data were reported. In the current study, source removal was implemented after fruit growth had plateaued, while sugar was still accumulating (8 DBH), and at the end of the cell expansion period (21 DBH).

Source removal only had a marginally significant depression of fruit FW ($P = 0.08$, Table 2), but markedly reduced fruit SSC. The effect of 50 % defoliation treatments on SSC was severe (producing fruit lower in SSC by 1 %; Table 2), while 25 % defoliation had a negligible effect. There was no significant interaction between the amount of leaves or branches removed (25 or 50 %), the timing of source removal (21 or 8 DBH), and the structure of the removed source (leaf or branch) ($P > 0.30$ for interactions).

Table 2. The effect of fruit load on fruit TSS, fresh weight, development time and plant photosynthetic rate on glasshouse grown cv. Hotshot rockmelons (*Cucumis melo* L). 'No fruit' treatment involved plants denied fruit set. Thinning was implemented 21 days before harvest. Harvest index (fruit dw/ total plant dw x 100%) and leaf weight index (leaf dw/ total plant dw x 100%), were determined. Probability values are reported for ANOVA analyses. LSD0.05 was calculated for photosynthetic rate (3.4) and leaf weight index (2.5).Dunnett's test was used to contrast 'one fruit' and other treatment means. Means with the same letter are not significantly different at p<0.05.

	n	fruit tissue TSS (%)	mean individual fruit FW (g)	total fruit FW per plant (g)	fruit development time (days)	harvest index (%)	Photosynthetic rate (µmol m^{-2} s^{-1})	Photosynthetic rate (µmol m^{-2} s^{-1} gDW^{-1})	leaf weight index (%)
one fruit	9	9.0 a	486 a	486 a	52	79 a	9.11 a	2.7	12.2 a
two fruit	8	7.8 b	312 b	625 b	52	80 a	11.23 a	3.5	11.8 a
thin to one fruit	7	8.8 a	395 c	395 c	52	72 b	9.24 a	2.9	15.9 b
thin to no fruit	8						3.56 b	2.3	45.0 c
no fruit	4						1.51 b	1.6	38.8 d
P (ANOVA)		0.0740	0.0001	0.0001	0.8590	0.0001	0.0001	0.2121	0.0001

Table 4. The effect of NBX (organic cytokinin) applied as a foliar spray on TSS (%), fruit fresh weight (g) and yield (t ha-1) for *Cucumis melo* L. plants grown on three commercial farms in Bourke NSW, Kununurra WA, and Kabra QLD. For the glasshouse trial, vegetative DW (g), harvest index (%) and leaf weight index (%) were recorded. NBX was delivered at the reccomended rate of 2-4 L/ha. The time of application varied for each location from three days before harvest (dbh) up to 14 dbh. Probablity values from ANOVA are documented.

application time:	14 dbh			10 dbh			7 dbh			3 dbh			7 dbh				
location and date:	Bourke 01			Kununurra 02			Kabra 01			Kabra 01			CQU glasshouse 01				
	TSS	FW	yield	TSS	FW	yield	TSS	FW	yield	TSS	FW	yield	TSS	FW	vegetative DW	HI	LWI
control	10.7	1325	27	8.4	1509	34	9.1	1596	22	9.1	1596	22	10.7	1292	88.5	58	22
NBX	11.3	1241	25	8.8	1512	37	8.9	1613	21	9.2	1603	20	9.6	1318	86.6	58	20
P (ANOVA)	0.02	0.06	0.65	0.24	0.97	0.28	0.46	0.70	0.67	0.59	0.88	0.16	0.12	0.82	0.88	0.92	0.14

Source manipulation – Chemically inhibiting vegetative growth: Plant bioregulators can improve fruit size, appearance and internal fruit quality, by directly affecting fruit growth and development, or by indirectly affecting fruit load, plant vigour and canopy architecture (Looney, 1993). The timing of application is important, with reference to fruit growth and sugar accumulation phases. When NBX was applied at 14 DBH (toward the end of fruit growth, 2001 Bourke trial), fruit SSC was improved (by 0.6 % SSC), and fruit FW was also marginally significantly higher (P = 0.06, increase of 100 g) (Table 3).

Applications closer to the time of harvest (10, 7 and 3 DBH) had no effect on SSC (with probability values for SSC further from 10 significance as NBX was applied closer to the time of harvest; Bourke at 14 DBH P=0.02, Kununurra at 10 DBH P=0.24, Kabra at 7 DBH P=0.46, and Kabra at 3 DBH P=0.88) (table 3). This result is consistent with a diversion of assimilate from vegetative growth to fruit storage, with the time frame of the response expected to be longer than that achieved through thinning fruit from vines. It is recommended that further work be conducted with respect to the timing of application of the growth retardant, and with more widely known retardants, such as paclobutrazol (gibberellin biosynthesis inhibitor).

Table 3. Fruit TSS, fresh weight and yield mean values for source organ removal treatments applied at either 21 or 8 days before harvest, implemented on field grown cv Hotshot melons in Kununurra WA. 2000 Factorial ANOVA P, and LSD values are documented.

treatment	TSS (%)	FW (g)	yield (t ha^{-1})
control	10.1	1456	21.6
25% branch removal 21 dbh	9.9	1468	21.8
25% branch removal 8 dbh	9.8	1461	24.3
25% leaf removal 21 dbh	9.7	1347	21.9
25% leaf removal 8 dbh	9.6	1410	23.5
50% leaf removal 21 dbh	9.4	1347	20.0
50% branch removal 21 dbh	9.3	1337	19.8
50% leaf removal 8 dbh	9.0	1318	22.0
50% branch removal 8 dbh	8.9	1338	20.8
LSD (0.05)	0.7	175	ns
source	probablity values		
percent	<0.001	0.08	0.27
organ	0.69	0.29	0.91
percent x organ	0.42	0.37	0.72
time	0.18	0.86	0.20
percent x time	0.36	0.63	0.84
organ x time	0.98	0.81	0.99
percent x organ x time	0.92	0.57	0.71

Source manipulation - Delaying Pollination: Delaying pollination in melon plants was expected to result in the setting of fruit on plants with a greater

than normal amount of source biomass (e.g. 30 and 165 g DW total plant biomass in control and delay set plants, corresponding to Table 5B). In the first glasshouse trial involving pollination scheduling, single fruit were set on 'delayed' and 'normal' plants. However, fruit were set on normal plants first, such that fruit development in the two treatments was confounded with time. Fruit SSC and FW were higher for the delayed treatment (9.5 % SSC, 1543 g for delayed cf. 6.3 % SSC, 1221 g for control). Harvest index was greater for the normal treatment, but there was no significant difference between treatments for leaf weight ratio (Table 5A).

In a second glasshouse experiment, the simultaneous setting of one fruit per plant for both normal plants and delayed plants allowed fruit to develop under the same environmental conditions, with the only difference being that delayed plants had more source biomass. Harvest index was greater for normal plants (59 cf. 38 % for delayed), whilst leaf weight ratio was lower for normal plants (23 cf. 26 %). Fruit development was approximately two days longer for delayed treatments (Table 5B). However, fruit SSC did not significantly differ between the two treatments, although delayed plants produced heavier fruit (1644 g FW) than normal plants (1442 g) (Table 5B).

This result is consistent with the interpretation that the extra photoassimilate made available during the fruit set and cell division and expansion phases will result in enhanced fruit weight rather than enhanced fruit SSC. The result is in agreement with that of Eischen et al. (1994), who also noted that there was no effect on fruit SSC in plants in which fruiting was delayed through use of net covers to exclude pollinators.

Table 5. The effect of delaying pollination, and the subsequent setting of one fruit per plant on plants differing in vegetative biomass, on fruit TSS, fruit fresh weight, fruit development time, total plant dry harvest index and leaf weight index. Experiment A treatment plants were seeded on the same day, whilst experiment B plants were seeded 20 days apart (data set common with Fig 5).

		fruit TSS (%)	fruit FW (g)	fruit development time (days)	total plant DW (g)	harvest index (%)	leaf weight index (%)
A	Delayed	9.5	1543	35	289.5	42.4	24.8
	Normal	6.3	1221	30	129.7	49.8	23.9
	P value	0.0001	0.0294	0.0003	0.0001	0.001	0.175
B	Delayed	12.3	1644	47	434.4	38.2	26.4
	Normal	12.5	1442	45	230.5	59.2	22.7
	P value	0.4841	0.0185	0.0407	0.0001	0.0001	0.006

Delaying pollination in-field (Table 5) meant that vines were able to direct assimilate resources into the continual promotion of lateral branch and female flower production, such that when netting covers were opened, more female flowers than normal were available for pollination. The additional assimilate supply facilitated the setting of more fruit per plant (7.1 fruit per delay plant cf. 4.3 control), but these fruit were smaller (by approximately 400 g FW) and lower in SSC than control fruit (by about 1.0 % SSC).

Where net covers where used to restrict pollination, allowing the setting of the first set (or 'crown' set) fruit only, fruit SSC and average FW were not significantly different from control treatment fruit (Fig. 5). The number of fruit per plant was significantly 11 less for plants set with the first crown fruit only (2.7 fruit per plant) than for control plants (4.3 fruit per plant), and consequently fruit yield per plant was 30 % lower in crown set plants than control plants (Table 5). This result was not expected.

We interpret this result as being a confounding of treatment effect with time, similar to the first glasshouse experiment (Table 5A). Further work should be undertaken using staggered plantings to avoid this problem.

The viability of fruit thinning as an agronomic tool: Of all the techniques considered, fruit thinning in the final two to three weeks before harvest gave the greatest increase in fruit SSC. However, it also resulted in the greatest decrease in overall yield. To remedy this drawback, plant density could be increased to maintain 'normal' yields (t ha-1) of fruit, although it was anticipated that increased plant density could cause a light (source) limitation in the crop. Kultur et al. (2001) propagated melons at 72,600 plants ha-1 and 36,300 plants ha-1 plant spacing, and reported no difference in fruit SSC between treatments, although fruit number, yield per plant and average fruit weight, were higher for less dense plantings, but yield (t ha-1) was lower.

Nerson (2002) reported that fruit SSC and average fruit weight decreased with increasing plant density (13.5 % SSC at 50,000 plants ha-1, 12.1 % at 80,000 plant ha-1, 10.4 % at 160,000 plants ha-1). In the Kununurra 02 trial, thinning increased fruit SSC only at the greater plant spacing of 50 cm (9.9 % for plants with 1 fruit cf. 8.6 % for control) and harvestable fruit yield was not significantly different at the two planting densities employed (31.4 cf. 36.9 t ha-1 for control plants, 28.5 cf. 35.4 t ha-1 for thinned plants, data not shown).

The other 'remedy' to decreased yield is improved price for 'sweet' fruit. Of course, the greatest value of thinning will be achieved when the mean of the population lies close, but under a quality control standard (i.e. greatest in the proportion of crop above a SSC standard). A simple Excel TM model was developed, based on the production costs estimated by Lovatt et al. (1998) and actually farm gate prices for 2001. Model details are found in Long (2004). Model inputs include yield (trays ha-1 or kg ha-1), the percentage of melons meeting a quality control grade ('sweet' SSC ≥ 10 %), and the price received for 'sweet' ($15 per 14 kg tray) and 'non-sweet' ($8 per 14 kg tray) melons.

The extra pre-harvest thinning cost was assumed to be the same cost as picking ($1047 ha-1). Thinning imposes extra cost, and reduces harvested yield, which must be balanced by an improved price on the product. For example, when thinning was imposed, yield was approximately halved, although 81 % of fruit had SSC above 10 % (data of Kabra trial, Fig. 4B, Fig. 5). At that time the market price was $8.00 per 14 kg tray and a return of $19.00 per 'sweet' tray would have been necessary for gross margin figures to

be equivalent for thinned production (approximately $5000 ha-1) (Fig 6). Alternatively, 95 % of fruit would need to be ‘sweet’, or the yield after thinning would need to be 16 t ha-1, to match the gross margin of normal production (Fig 6).

From a practical perspective, thinning may not be an appropriate pre-harvest technique if leaves (source organs) are damaged by trampling during the thinning 12 treatments. However, a system involving workers (human or robotic, e.g. Edan and Miles, 1993) on a boom, allowing thinning without plant destruction, could be engineered.

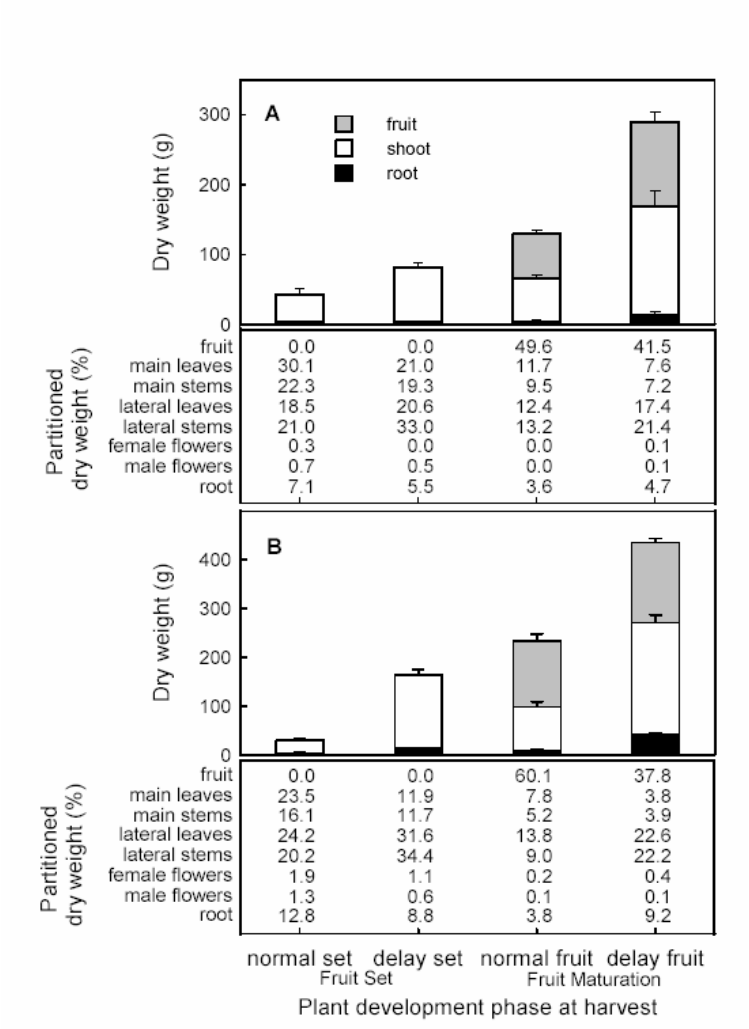


Figure 6. The effect of limiting fruit set to one fruit per plant on biomass allocation in *Cucumis melo* L. plants (data set common to Fig. 5 and Table 6). Data reported for harvests made at the time of fruit set and at fruit maturation. Experiment A are treatment plants seeded on the same day, whilst experiment B are treatment plants seeded 20 days apart.

5. Irrigation

Introduction

Poor eating quality is the main reason given by consumers for why they do not purchase more muskmelon (Cucumis melo L. reticulatus group) in Australia (Australian Melon Association, 2003). One criterion commonly used to assess fruit eating quality is soluble solids concentration (% SSC) of the flesh. Mutton et al. (1981) recommended a minimum SSC of 10%, while a U.S. standard recommends a minimum of 9.0% (Kader, 2002).

In early fruit development, assimilate from photosynthesis is directed mainly into fruit growth, and it is only in the final two weeks of fruit development, after fruit expansion has ceased, that sugars accumulate in the fruit resulting in an increase in SSC. This carbohydrate partitioning is regulated by high soluble acid invertase activity during fruit growth and then by high sucrose phosphate synthase activity during the sugar accumulation phase (Lester et al., 2001).

Muskmelon do not accumulate significant amounts of starch, so all carbohydrate for fruit growth or sugar accumulation must come from current photosynthesis in the source leaves (Wein, 1997). Thus the impact of a source or sink manipulation on muskmelon fruit quality and harvestable yield will depend on the timing of the manipulation or stress (El-Keblawy and Lovett-Doust, 1996; Long et al., 2004; Valantin et al., 1998) and it is well known that water stress reduces stomatal conductance and the rate of photosynthesis in mature source leaves (Heermann et al., 1990).

It is therefore likely that water stress during vegetative growth will reduce the photosynthetic capacity of the plant, and thus potentially reduce harvestable fruit biomass. Water stress during early fruit development may affect fruit cell number, and thus final fruit size (Higashi et al., 1999). Importantly, stress imposed during the later part of fruit development, during the sugar accumulation phase following fruit cell expansion, is expected to have the greatest impact on fruit SSC relative to the impact on fruit biomass (Long et al., 2004).

The impact of plant water status during the life of muskmelon crops on fruit quality and yield parameters has been variously reported in the literature. Wells and Nugent (1980) reported that rainfall in the final stages of fruit development affected muskmelon SSC either positively or negatively, depending on cultivar, and that SSC was most influenced by rainfall during the five days preceding harvest. Phene et al. (1987) imposed different water deficit regimes during vegetative growth using several irrigation practices (sub-surface, high frequency surface, and low frequency surface trickle) and reported no effect on fruit SSC between treatments. Other quality factors such as ground spot and fruit rot were differentially affected by treatments.

In this study, the effect of imposing water stress before and during harvest on muskmelon yield and fruit SSC was tested in two separate field experiments.

Materials and Methods

Experiment 1

The first experiment was planted on 22nd February 2001 on a commercial farm near Bourke, New South Wales, Australia (lat. 30°2'S long. 145°57'E). 'Dubloon' muskmelon plants were established by transplanting through black plastic mulch at 50 cm spacing into single row beds 2 m between centres into which trickle irrigation tube had been previously buried to a depth of 30 cm and pre-plant fertilizer applied. The field sites were uniform in soil type and laser-levelled. The soil was a red sandy loam. Total pre-plant base and fertigated nutrients applied during the crop were: 50N, 17P, 113K, and 15Ca kg/ha.

Irrigation water was from the Murray Darling River, and the electrical conductivity of the water was 500-700 µS/cm. After an initial irrigation at transplant, all treatments were maintained between field capacity and the refill point from flowering until one week before the start of harvest. Irrigation deficit (water stress) treatments were imposed as follows: (i) no stress, (ii) stress during the week before the start of harvest, (iii) stress from one week before the start of harvest including the harvest period. Tensiometers were installed to 25 cm depth to measure soil moisture. Soil moisture was maintained between 10 and 15 kPa of soil suction, but allowed to dry to 40 kPa for the stress periods.

The experiment was three treatments in a Completely Randomised Design with 4 replicates. Individual plots were 10 m long, and a 2 m long section of row was selected from each plot and all fruit were harvested for yield and fruit quality measurements. There would have been minimal movement of water between adjacent plots. Muldoon et al. (1999) reported that for muskmelon plants growing in clay soil with a trickle tube 10 cm deep, water moved laterally only about 40 cm from the trickle tube. From our observations during the experiments, the lateral movement of water was less than 35 cm from the buried trickle tube. Moreover, if any lateral leakage of irrigation water into adjacent plots had occurred, it would have minimised water stress treatment effects, not accentuated them.

Experiment 2

The second experiment was set up on the same farm but in the following year and on a heavy clay soil. The plants were established by direct seeding into bare soil on 30th November 2001 at 50 cm spacing into single row beds 2 m between centres into which trickle irrigation tube had been previously buried to a depth of 30 cm and pre-plant fertilizer applied. The field site was uniform

in soil type and laser-levelled. Total pre-plant base and fertigated nutrients applied during the crop were the same as for experiment 1.

Soil moisture was measured using a single capacitance-based Enviroscan (Sentek Australia) soil moisture probe per treatment. Each probe had sensors at 10, 20 and 50 cm depth. The field capacity of the soil was 50 mm of soil water per 10 cm soil depth and the refill point was approximately 15 mm of soil water per 10 cm soil depth. After an initial irrigation at sowing, all treatments were maintained between field capacity and the refill point from flowering until one week before the start of harvest. Water stress was defined as allowing soil to dry to 8-10 mm soil water per 10 cm soil depth. Water stress treatments were: (i) no stress, (ii) stress imposed at the start of harvest, (iii) stress during the week before the start of harvest, and (iv) stress during the week before harvest and including the harvest period.

The experiment was set up with 4 treatments in a Split Block Design with 3 blocks, each having 2 cross treatments, giving a total of 24 plots. Individual plots were 10 m long, and a 2 m long section was selected from each plot for yield and fruit quality measurements.

Physiologically mature fruit (at abscission or 'full-slip') from both experiments were harvested daily (7th – 18th May 2001 for experiment 1 and 9th – 18th February 2002 for experiment 2). The average number of fruit per plant was calculated to be between about 2 and 3 fruit (Experiment 1: no stress 3.1 fruit per plant, stress before harvest 2.4, stress before and during harvest 3.1; Experiment 2: no stress 1.9, stress during harvest 2.0, stress before harvest 1.8, stress before and during harvest 1.9). Each fruit was weighed, and the total fresh weight of fruit per 2 m subplot was converted into yield (t/ha). One 15 mm diameter core of tissue was taken from an equatorial position on each side of each muskmelon, with the ground spot facing downward. The outer 10 mm of tissue was removed (included skin and green) then the next 10 mm of tissue was sampled, crushed in a hand operated garlic press and the SSC (^{o}SSC scale) of the resulting juice measured on a Bellingham and Stanley (Kent, United Kingdom) RFM 320 temperature compensated digital refractometer.

Data analysis

The SAS 6.12 software package (Cary, NC, USA) was employed for ANOVA of data. Least significant difference (LSD, $P = 0.05$) was calculated to facilitate means separation for ANOVA models that were significant ($P < 0.05$). Mean and standard error values are reported where the corresponding ANOVA model was not significant ($P > 0.05$).

Results and Discussion

There was no rain during the treatment periods for experiment 1, and only 0.8 mm just prior to the start of harvest for experiment 2.

In experiment 1, treatments in which an irrigation deficit was implemented immediately before and during harvest produced fruit significantly lower in SSC than those plants delivered adequate water during harvest (no stress 11.2% SSC, stress before harvest 8.8% SSC, stress before and during harvest 9.5% SSC) (Fig. 1). Tensiometers were maintained at 40 kPa during the 'stress' period, which was in accord with the Queensland Department of Primary Industry's recommended level of 25-40 kPa for sandy loam soil during the week before harvest and during harvest (Lovatt et al., 1997). This irrigation deficit also reduced fruit weight and total yield, but the difference between treatments for the latter was not significant (Fig. 1).

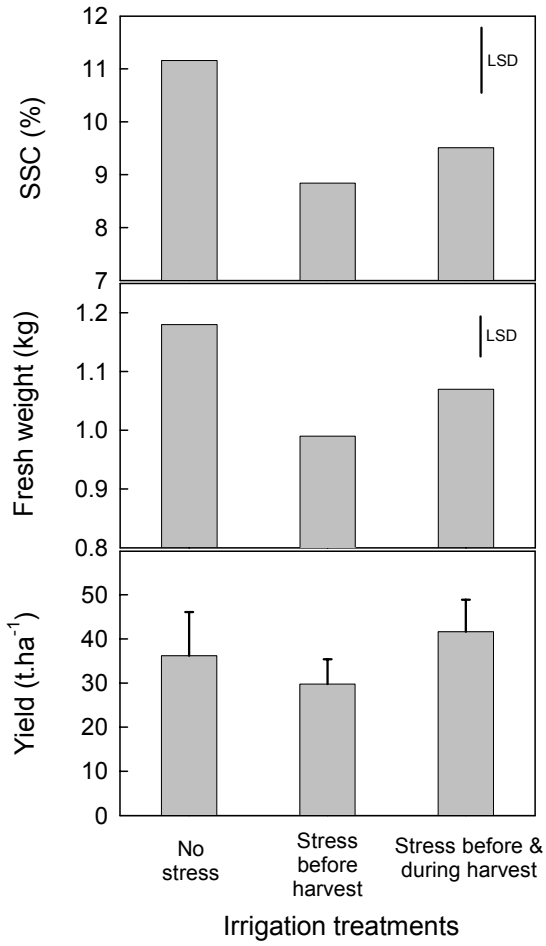


Figure 1. Irrigation deficit treatments imposed from 7 DBH to the beginning of harvest, and from 7 DBH including the harvest period, for field grown cultivar Dubloon plants in Bourke 2001. Mean and LSD values are reported for SSC and weight (n = 96-124, P < 0.00), se reported for yield (n = 4, P = 0.42).

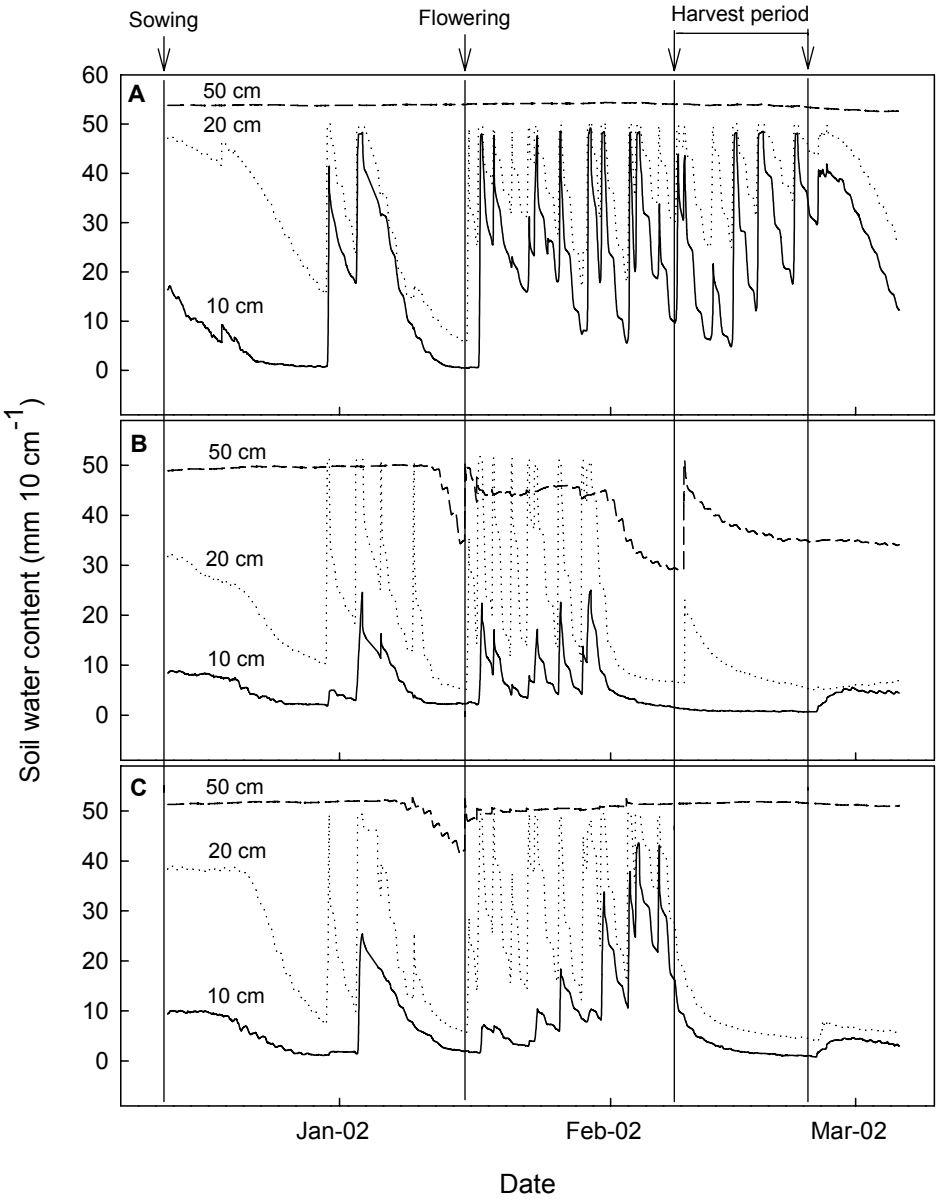


Figure 2. Soil moisture for a trial in Bourke, New South Wales (2002 harvest season) recorded by Enviroscan (Sentek Australia) probes at 10, 20 and 50 cm, for deficit (stress) free irrigation from flowering through to the end of harvest (**A**); for stress during the week before harvest and including the harvest period (**B**); and for stress implemented at the start of harvest (**C**). Field capacity was determined to be 50 mm of soil water, and the refill point was 15 mm. Note, treatments are common to Fig. 3, and the 'stress before harvest' Enviroscan graph is not presented due to instrument malfunction and lost data.

In experiment 2, the record of soil water content (Fig. 2) confirmed that the treatments effectively controlled available soil water for the crop. Similar effects on SSC and fresh weight were recorded as in the previous year's experiment. When an irrigation deficit was applied during either the harvest

period, before harvest, or during both, fruit SSC was reduced compared to plants maintained with adequate water (e.g. no stress 10.6% SSC cf. 9.0% SSC for fruit from treatments with stress before and during harvest, Fig. 3). Fruit weight and total yield were also detrimentally affected; no stress fruit fresh weight 1700 g, yield 31 t.ha-1; stress before and during harvest fruit fresh weight 1300 g, yield 25 t.ha-1 (Fig. 3).

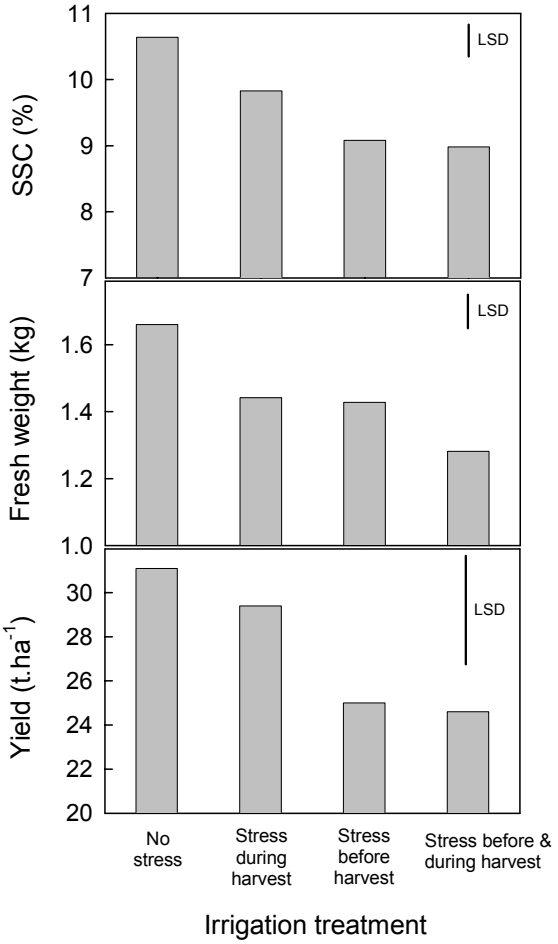


Figure 3. Irrigation Treatments - Experiment 2. Mean and LSD (P = 0.05) values for fruit soluble solids concentration (SSC), fresh weight and yield (ANOVA P < 0.05). Irrigation deficit treatments were imposed at the start of harvest (stress during harvest), during the week before the start of harvest (stress before harvest), and during the week before harvest and including the harvest period (stress before and during harvest), for field grown 'Dubloon' muskmelons in Bourke, New South Wales (2002 harvest season). Data are common to Fig. 2.

The practice of allowing soil moisture to deplete close to and during harvest as recommended by Lovatt et al. (1997) and Hulme et al. (2002) reduced fruit quality in our experiments. Moisture stress during this critical period of sugar accumulation in the fruit was likely to have reduced assimilate supply to the fruit by slowing the rate of photosynthesis in the source leaves, reducing sugar accumulation. A secondary effect noticed in both experiments was that fruit from water stress treatments abscised earlier than well-watered treatments (data not shown).

The common practice of reducing irrigation close to harvest may be an over-response to reported negative effects of excessive irrigation close to harvest. Lester et al. (1994) showed that additional water close to harvest produced fruit with lower SSC and greater volume, whilst Wells and Nugent (1980) demonstrated that rainfall events close to harvest detrimentally affected muskmelon fruit SSC (depending on cultivar). Further, with a sudden improvement in plant water potential, fruit storage cells may become hyperosmotic relative to their apoplast, leading to an uptake of water into these cells and the increase in fruit fresh weight, but the dilution of accumulated sugar.

Water-logging causes root anoxia and impedes root respiration (Barrett-Lennard, 2003) which in turn slows the uptake of water, causes stomata to close and ultimately retards photosynthesis (Lester et al., 1994). Kroen et al. (1991) reported that muskmelon plants subjected to root flooding for four days close to harvest showed decreased root respiration (by 30%) and decreased sucrose accumulation in fruit (by 36% and 88% for inner and outer mesocarp tissue, respectively). The decrease in the rate of sugar accumulation in the fruit was attributed to an increase in the glycolytic activity of the anaerobic roots and the subsequent increased transfer of carbohydrates to the roots at the expense of the fruit (Kroen et al., 1991; Su et al., 1998).

Future work on irrigation scheduling should focus on the periods pre-harvest and during harvest, and should include studies encompassing irrigation scheduling on different soil types and for different muskmelon cultivars.

6. Nutrition

Introduction

Adequate nutrient levels in the plant, especially nitrogen are required to support the photosynthesis required to the accumulation of high soluble sugars in the fruit and for the production of a normal fruit net (Pew and Gardner 1972; Nerson 1992). Leaf photosynthetic rate is very sensitive to plant nutrient levels (Muthuchelian 1992; Fichtner et al. 1993; Walker et al. 1993), especially nitrogen and would explain the correlation reported in the literature between optimal nutrition and high sugar accumulation in fruit.

Calcium is also critical in the development of high quality melons. Calcium deficiency has been reported to reduce soluble solids concentration, netting, tolerance to chilling injury and fruit firmness (Sombrink et al. 1995).

Calcium accumulation in the fruit occurs mainly in the first 20 days after anthesis, and sufficient calcium must be available to the developing fruit during this time. Late foliar calcium applications are ineffective at correcting calcium deficiency (Bernadec et al. 1996).

Boron deficiency has a similar effect on fruit quality to calcium deficiency, and can be corrected by foliar boron applications up to 7 weeks after transplant (Sombrink et al. 1995).

A major focus of the proposed project will be to determine the optimum nutrient application rates, for the production of high sugar content rockmelons, while at the same time not stimulating excessive vegetative growth.

Experiment 1 –NPK experiment, Bourke, NSW

Materials and Methods

Four rates of four levels of nitrogen (40, 60, 120,150 kg N/ha), four levels of phosphorus (25, 40, 70, 100 kg P/ha) and three levels of potassium (45, 60, 90, 150 kg K/ha) were applied to 10m long plots in a randomized complete block experiment with 3 replicates (n=3). These treatments were compared a control treatment where N,P and K were applied at 60, 40 and 60 kg/ha respectively. For each treatment, the elements other that the one being tested was applied at the rate used for the control.

The fertilizers were applied in a 40 cm wide band on 1.2m wide beds and incorporated using a rotary hoe. Rockmelon plants (cv Durack) were planted by direct seeding on 30th October into the clay loam soil and irrigated by trickle irrigation tape which was buried 15 cm below the soil surface.

An additional 23 kg/ha N and 2 kg/ha P were applied by fertigation to all treatments 3 weeks after planting. An additional 5 kg/ha of N and 45 kg/ha of K were applied to all treatments by fertigation during fruit development.

Youngest fully expanded leaves (YFEL) were sampled at mid fruit development, 20 leaves per plot and sent to a NATA accredited laboratory for tissue analysis.

The melons were harvested by hand-picking a fruit which was at the full slip stage of maturity, starting on the 9th January and continuing until all fruit had been harvested, about 7 days later. Harvested fruit was counted and weighed. SSC was measured by taking cores from either side of the fruit and crushing a section of fruit mesocarp 1 cm from the outside of the fruit, and pouring the juice onto a digital refractometer. Fruit was then cut from apical to distal end, and flesh firmness was measured using a penetrometer to measure the resistance at three points in the mid area of the mesocarp.

Results and Discussion

Nitrogen. The yield of rockmelon fruit increased as the supply of N was increased up to 120 kg/ha. The highest rate of N supply, 150 kg/ha reduced fruit yield, suggesting this rate was toxic (Fig. 1). Fruit soluble solids levels were not affected by the rate of N supply, even up to the highest rate of 150 kg N/ha (Fig. 2). This effect of high N supply not reducing fruit soluble solids levels is consistent with known effects of N supply on photosynthetic rate, but may differ from the expectations of industry where growers might expect high rates of N to cause a reduction in fruit soluble solids.

Nitrogen supply reduced flesh firmness at rates higher than 40 kg N/ha, and this may be a consideration if the fruit is destined for processing into a fresh cut product (Fig. 3).

The N concentration in the youngest fully expanded leaves was 4.2 % at an N supply of rate of 120 kg/ha which corresponded to the highest yield and quality. It is proposed therefore that the reference leaf tissue N level for rockmelons should be set at 4.2%

Phosphorus. The yield of rockmelons was higher at each additional rate of phosphorus applied up to 100 kg P/ha (Fig. 1). P supply had no significant effect of fruit soluble solids (Fig. 2), and no effect on fruit firmness (Fig. 3). This suggests that P should be applied at a high rate compared to normal commercial applications to maximise yield, without fear of adverse effects on fruit quality. The highest rate of P supply resulted in a leaf P concentration of 0.49% and the authors suggest the leaf tissue target P level should be close to this figure (Fig. 4).

Potassium: increasing the rate at which potassium was applied to the crop did not significantly increase yield until 150 kg K/ha has been applied (Fig 1). It is worthwhile bearing in mind that after the basal applications had been made, and additional 45 kg K/ha was applied by fertigation to all plots. This means the total amount of K applied to the crop at the highest K rate was 195 kg K/ha, a high rate compared to normal commercial practice where around 80 kg K/ha is more common.

The potassium rates did not have any clear effect on fruit soluble solids, except a slightly higher level at the lowest level of K supply (Figure 2). This finding differs from recent published work which suggest K is positively correlated with fruit soluble solids level (Lester, Jifon et al.).

There was a slight effect of K supply on flesh firmness, but the trend is unclear and difficult to interpret. The flesh firmness at all levels of K supply is adequate for fresh or processed fruit. A leaf K concentration of 3.1 % dwt corresponds with the highest yield, and should be considered as target tissue K level (Fig. 4).

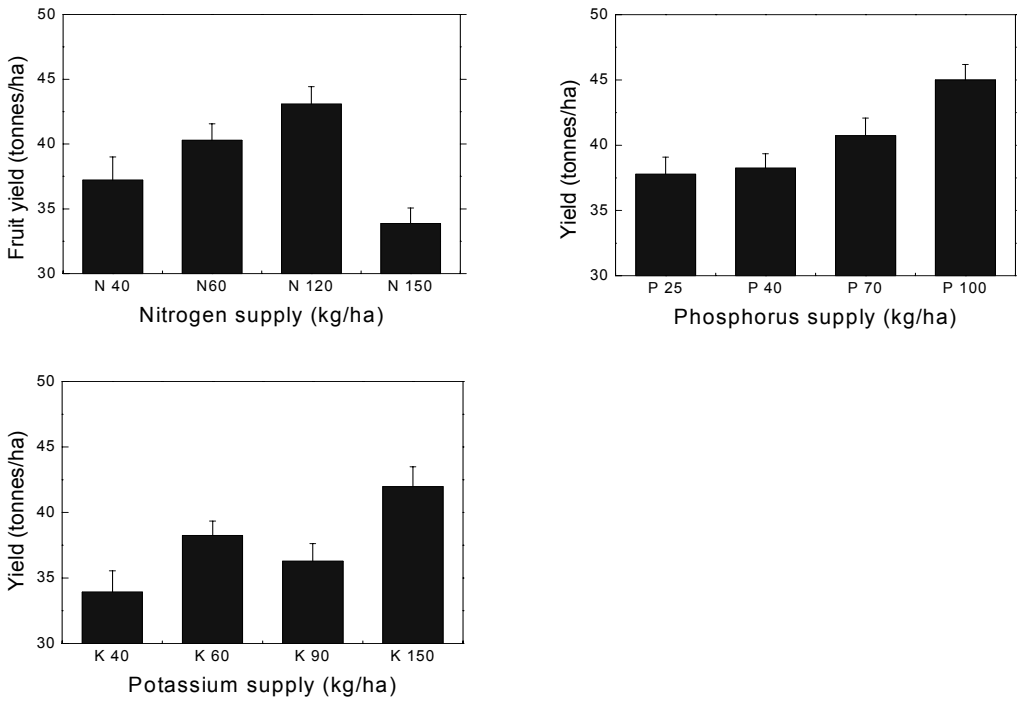


Figure 1. Effects of varying N, P and K supply on rockmelon fruit yield, Bourke

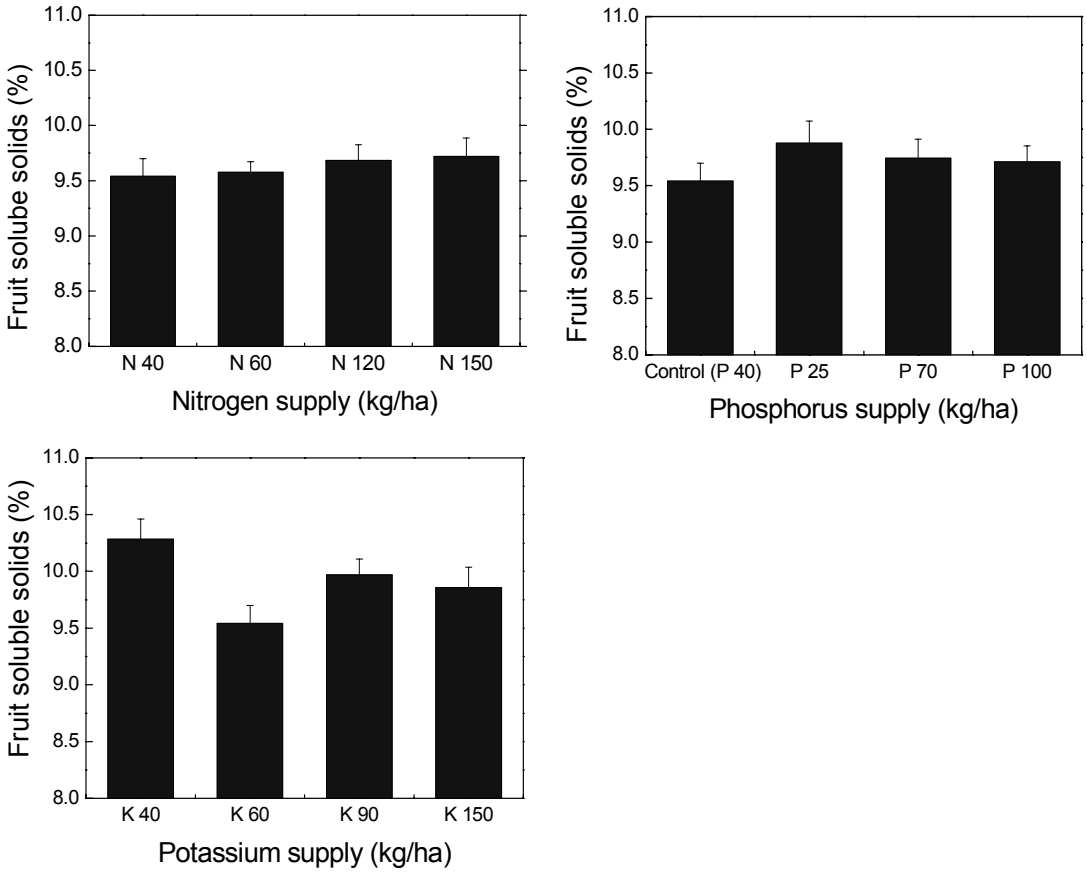


Figure 2. Effects of varying N, P and K supply on rockmelon fruit soluble solids, Bourke

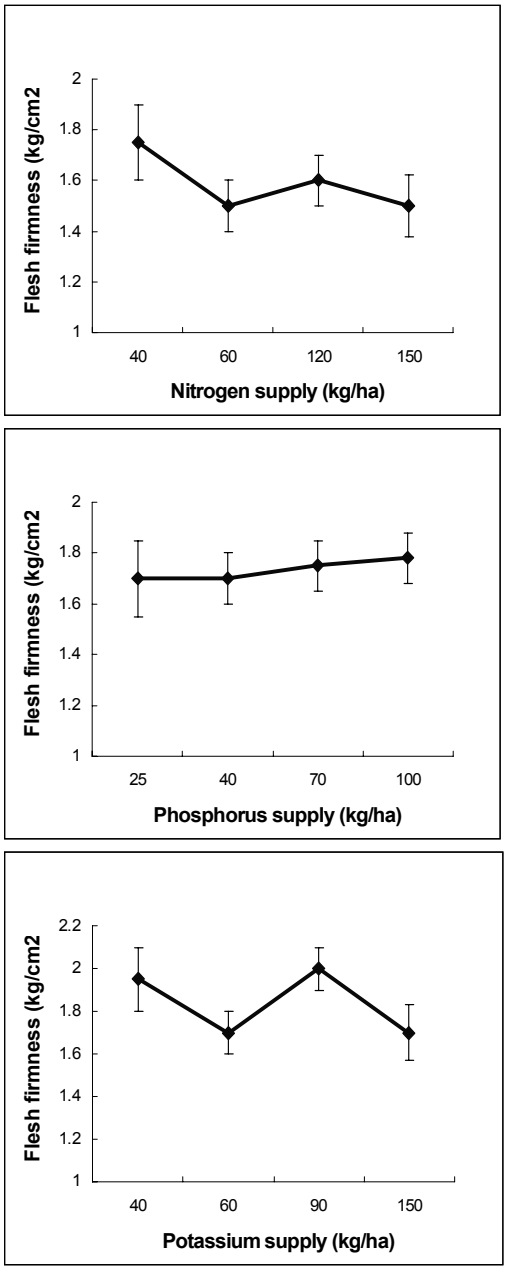


Figure 3. Effects of varying N, P and K supply on rockmelon fruit firmness, Bourke

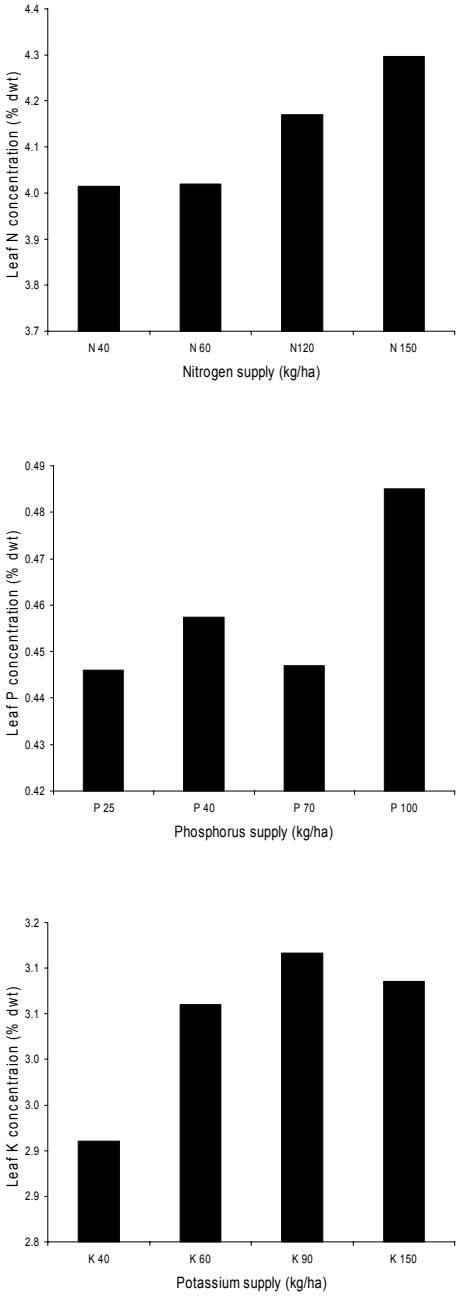


Figure 4. Effects of varying N, P and K supply on rockmelon leaf nutrient levels

Table 1. Rockmelon Youngest Fully Expanded Leaf – Mid – Fruit Development.

Treatment	N %	NO3-N ppm	P %	K %	Ca %	Mg %	S%	Mn ppm	Zn ppm	B ppm	Cu ppm	Fe ppm	Mo ppm	Na %	Cl %
Control	3.9	375	0.46	3.1	5.6	1.3	0.51	482	385	140	9.5	300	0.05	0.43	2.3
39 kg/ha N	4.0	250	0.50	3.1	5.2	1.3	0.54	539	407	137	10.3	390	0.07	0.38	2.4
55 kg/ha N	4.0	485	0.41	2.8	5.8	1.4	0.51	378	285	106	9.0	311	0.05	0.33	2.3
116 kg/ha N	4.2	313	0.49	3.3	4.5	1.1	0.50	413	295	110	10.9	337	0.14	0.33	2.3
146 kg/ha N	4.3	880	0.51	3.5	5.5	1.4	0.58	445	381	132	10.6	616	0.06	0.50	2.4
25 kg/ha P	3.9	249	0.45	3.0	5.5	1.3	0.55	400	297	142	9.5	331	0.09	0.42	2.6
71 kg/ha P	4.1	504	0.45	3.0	5.1	1.3	0.55	395	297	121	9.7	269	0.08	0.34	2.0
102 kg/ha P	4.2	375	0.49	3.1	5.6	1.3	0.52	476	352	125	10.1	270	0.09	0.36	2.2
43 kg/ha K	4.0	368	0.48	2.9	5.2	1.3	0.51	455	362	135	9.8	318	0.10	0.39	2.5
89 kg/ha K	4.1	285	0.45	3.1	5.2	1.4	0.59	383	281	121	9.2	206	0.08	0.37	2.3
150 kg/ha K	4.2	436	0.49	3.1	5.3	1.3	0.52	465	347	133	11.0	330	0.10	0.39	2.2
24 kg/ha Ca	4.1	369	0.47	3.0	5.6	1.3	0.55	384	287	145	10.1	283	0.07	0.44	2.5
40 kg/ha Ca	4.2	856	0.50	3.2	4.5	1.1	0.59	421	342	106	11.2	404	0.12	0.32	2.1
70 kg/ha Ca	4.2	509	0.49	3.4	4.8	1.3	0.51	441	337	100	10.1	348	0.05	0.36	2.4
31 kg/ha S	4.1	418	0.49	3.1	5.4	1.3	0.51	422	315	137	10.8	331	0.10	0.40	2.6
47 kg/ha S	4.2	832	0.46	3.3	4.7	1.2	0.52	429	337	122	9.2	392	0.07	0.39	2.3
65 kg/ha S	3.9	276	0.43	2.8	5.2	1.3	0.48	374	279	146	9.2	301	0.08	0.36	2.5

Table 2. Rockmelon leaf nutrient levels, Cunnamulla, mid fruit development stage.

		Treatment						
Nutrient		**H 150**	**H 300**	**H 600**	**H 150 + SS 600**	**H 300 + SS 600**	**H 600 + SS 600**	**H 150 + N 9**
Nitrogen	%	2.3	2.9	3.3	2.5	3	3.1	2.6
Phosphorus	%	0.23	0.27	0.29	0.22	0.26	0.25	0.27
Potassium	%	2.01	2.2	2.38	1.68	2.23	2.1	1.94
Calcium	%	5.04	3.67	3.51	5.67	4.67	5.47	5.34
Magnesium	%	0.65	0.59	0.55	0.66	0.63	0.69	0.61
Sodium	%	0.17	0.097	0.13	0.16	0.18	0.2	0.13
Sulphur	%	0.53	0.49	0.54	0.83	0.68	0.93	0.86
Zinc	mg/kg	17	23	19	18	16	17	28
Iron	mg/kg	200	200	190	220	200	220	160
Copper	mg/kg	6.4	7.1	7	6.8	6.8	7.1	8.7
Manganese	mg/kg	110	100	100	120	120	140	87
Boron	mg/kg	65	64	60	47	68	66	61

Experiment 2 – Balanced NPK experiment, Cunnamulla, Qld

The first nutrition experiment suggested that that the best yield could be obtained by applying N at 120 kg/ha, P at 100 kg/ha and K at 150 kg/ha, with no adverse effects on fruit firmness or SSC.

The first experiment however did not answer the question of what would be the effect of applying different rates of NPK together, so the second experiment was designed to test this scenario on yield and quality of rockmelon fruit in a commercial environment.

Materials and Methods

At Back O Bourke Fruits farm at Cunnamulla, SW Qld, about 300 km north west of the site used for the first nutrition experiment and on a similar soil type, three rates of NPK fertilizer (Hydro complex NPK 12.4:5:14.7) either with or without additional P supplied as single super phosphate (9% P) were applied. The fertilizers were applied as a basal pre-plant application in a 30 cm wide band and cultivated in with a rotary hoe. Trickle irrigation tube was installed on the soil surface, black plastic mulch was laid and beds were formed in the same operation. Rockmelons cv. Dubloon were planted as transplants. Each treatment was replicated 6 times in a completely randomised design (n=6). Yield and quality were assessed as in experiment 1.

An additional 23 kg/ha N and 2 kg/ha P were applied by fertigation to all treatments 3 weeks after planting. An additional 5 kg/ha of N and 45 kg/ha of K were applied to all treatments by fertigation during fruit development.

Youngest fully expanded leaves (YFEL) were sampled at mid fruit development, 20 leaves per plot and sent to a NATA accredited laboratory for tissue analysis.

Table 3 – Treatments Experiment 2

	Treatment	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)
1	Hydrocomplex 150 kg/ha	18.6	7.5	22
2	Hydrocomplex 300 kg/ha	37.2	15	44
3	Hydrocomplex 600 kg/ha	74.4	30	88
4	Hydrocomplex 150 kg/ha + super 600 kg/ha	18.6	61.5	22
5	Hydrocomplex 300 kg/ha + super 600 kg/ha	37.2	69	44
6	Hydrocomplex 600 kg/ha + super 600 kg/ha	74.4	84	88

7	Hydrocomplex 150kg/ha + Nutrismart 900kg/ha	N/A	N/A	N/A

Results and Discussion

The highest yield of 67 tonnes/ha was obtained by applying NPK at 40, 15 and 88 kg/ha respectively (Hydro complex at 600 kg/ha) Further increase in NPK application rate did not increase yield, however, the additional fertilizer did result in 1^{o} SSC higher fruit soluble solids. Extra phosphorus, up to 84 kg P/ha resulted in a additional 0.5^{o} SSC over the highest NPK rate.

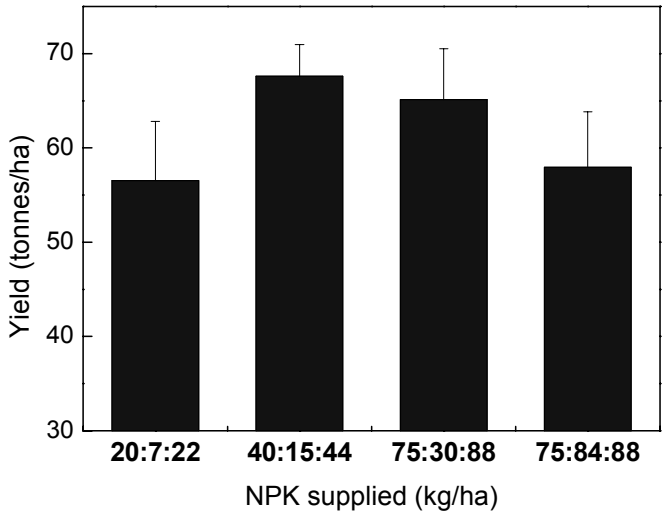


Figure 5. Effect of basal fertilizer rates on yield of rockmelon fruit.

The lowest rate of applied NPK resulted in the lowest yield which was consistent with results of experiment 1. The highest yields were obtained by supplying 40, 15 and 44 kg/ha NPK respectively in the base fertiliser plus an additional 23 kg/ha N and 45 kg/ha of K applied through trickle irrigation. This result was significantly different to experiment 1, where maximum yields were achieved at much higher NPK rates and suggests that higher rates of a single element may compensate for low supply of individual elements. The very high P rates were also not effective in increasing yield (Fig. 4).

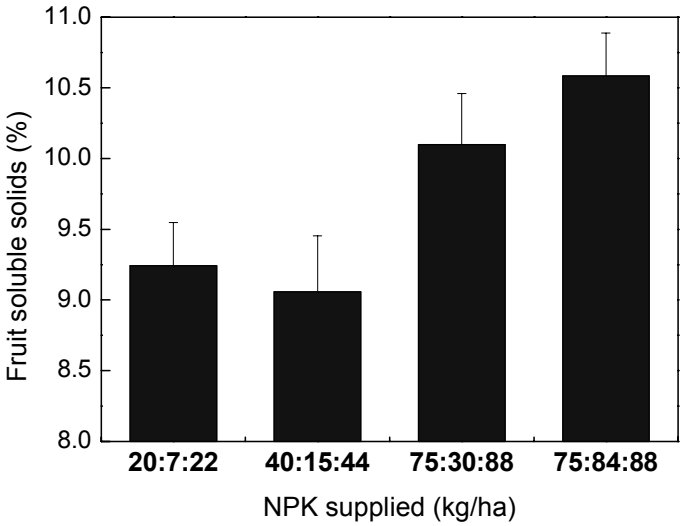


Figure 6. Effect of basal fertilizer rates on soluble solids concentration of rockmelon fruit.

The effect of supplying different rates of NPK in combination were on soluble solids concentration were different to effects on yield. The highest SSC was obtained when NPK was applied at 75, 30 and 88 kg/ha respectively, and additional P to 84 kg/ha in the basal application did not significantly further increase fruit SSC (Fig. 6).

Fruit size was not significantly affected by basal NPK application rate (data not shown). Higher levels of NPK supply slightly reduced fruit firmness, however increasing the phosphorous supply in the basal fertilizer significantly increased fruit firmness to a level higher than that was achieved using low NPK rates.

Conclusion

The results indicate that for the best combination of yield and quality, NPK should be applied at about 100, 30-50, 135 kg/ha respectively with about 75% of the N and K applied pre-plant and the balance applied later by fertigation. With N, the balance should be applied in the vegetative phase, and the K should be applied during fruit development.

The nutrient levels in the youngest fully expanded leaves should be used as guide to fertilizer rates on individual farms. New target tissue levels for managing crop nutrition are suggested in Table 4.

Table 4. Proposed new leaf tissue nutrient standards for rockmelon youngest fully expanded leaves

Nutrient		Flowering to Fruit Set Stage			Mid Fruit Development		
Nitrogen*	%	5.5	...	6.5	4.0	...	4.5
Phosphorus	%	0.6	...	0.8	0.4	...	0.6
Potassium	%	4.0	...	5.0	3.0	...	3.5
Calcium	%	3.5	...	4.5	4.5	...	5.5
Magnesium	%	0.7	...	1.0	0.7	...	1.0
Sodium	%	0.0	...	0.5	0.0	...	0.50
Sulphur	%	0.5	...	1.0	0.5	...	1.0
Zinc	mg/kg	20	...	400	20	...	400
Iron	mg/kg	40	...	450	40	...	450
Copper	mg/kg	6	...	20	6	...	20
Manganese	mg/kg	20	...	500	20	...	500
Boron	mg/kg	50	...	200	50	...	200

7. Calcium Dipping

Introduction

Calcium is important in maintaining the membrane integrity of rockmelon and honeydew fruit cells (Lester et al. 1994). If fruit tissue is low in calcium, edible fruit tissue can break down faster than normal and is also prone to leaking cell contents into the seed cavity.

Lester et al. (1994) has shown that calcium can be supplied directly to fruit through the skin by dipping harvested fruit in a calcium solution. Further, Lester has shown that this externally-applied calcium is effective at extending shelf life of harvested fruit. After rockmelon fruit are harvested, there is a rapid movement of calcium away from the outer flesh of the melon toward the seeds. This movement can deplete the calcium levels in the outer flesh of the fruit.

Research on rockmelons has clearly shown that if calcium can be supplied directly to the fruit within a couple of hours of harvest, it is possible to extend postharvest life of the fruit. This is especially true if the calcium levels available to the plant during fruit development were below the optimum.

Materials and Methods

Experiment 1: Fruit Dipping Trials at Cunnamulla

Rockmelon fruit were harvested from the commercial crop at Back O Bourke Fruit, Cunnamulla, and graded for size so that all fruit weighted between 1.3 – 1.5 kg.

As soon as possible after harvest (within 2 h) the fruit was divided into 2 x matched samples of 20 fruit each. One group of fruit was dipped in a 2.4 g/L calcium solution (12% calcium product diluted to 2L per 100L of water – Melon Dip, Stoller Australia) for 15 minutes

The remaining sample was dipped in water for 15 minutes. Fruit was held at 5 ^{o}C for 28 days, and internal and external appearance rated every 7-10 days.

Experiment 2: Fruit Dipping Trials at Mildura

Rockmelon fruit were harvested from the commercial crop at Thurla Farms and graded for size so that all fruit weighted between 1.3 – 1.5 kg.

The fruit was divided into 3 x matched samples of 40 fruit each. As soon as possible after harvest (within 2 h), one group of fruit was dipped in a 2.4 g/L calcium solution (12% calcium product diluted to 2L per 100L of water – Melon Dip, Stoller Australia) for 15 minutes, another group was dipped in the same concentration of calcium plus 1L/100L of a solution containing 0.005% Indole-3-Butyuric Acid, and a third group of 40 fruit was dipped in water for 15 minutes. The fruit was then held at 5 ^{o}C and rated for internal and external quality. Flesh soluble solids and firmness were measured using standard methods.

Results and Discussion

Experiment 1 showed that fruit dipped in Melon Dip maintained an acceptable internal and external appearance for about 21 days, whereas untreated fruit lasted only 14 days when stored at 5 ^{o}C. There were no differences between dipped and undipped fruit on fruit firmness (Fig. 1).

Experiment 2 showed that after 28 days storage at 5 ^{o}C after harvest, the control fruit had reached maximum yellowing and external skin browning, the rind shrinkage was 3 out of 5 and the external firmness had fallen to 2.5 out of 5. The skin of calcium dipped fruit however had become only slightly more yellow and brown, rind shrinkage was minimal and external firmness had only fallen to 4 out of 5. Adding IBA to the calcium dip slightly delayed rind shrinkage over the effect of calcium alone (Fig. 2).

These trials suggest that internal and external appearance can be maintained in good condition for longer if fruit can be dipped in a calcium dip (or possible spray) in the fruit packing line to extend shelf life of rockmelons.

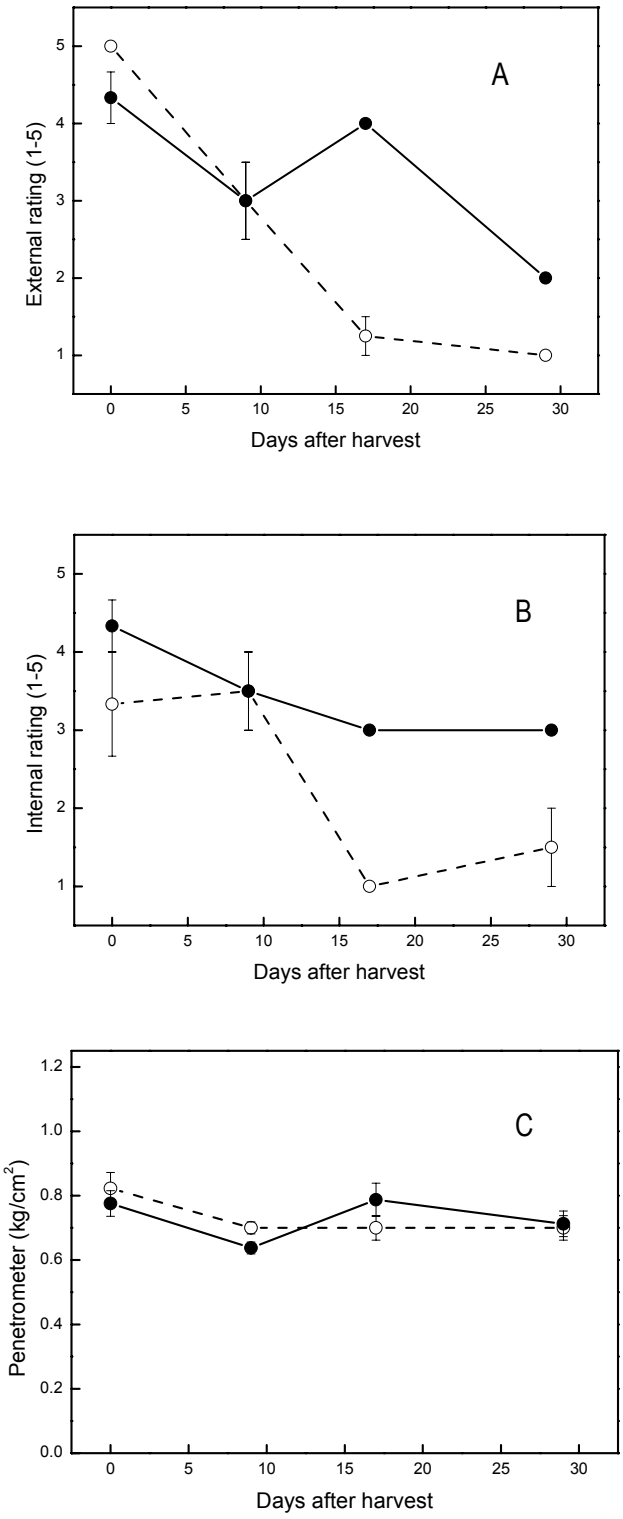
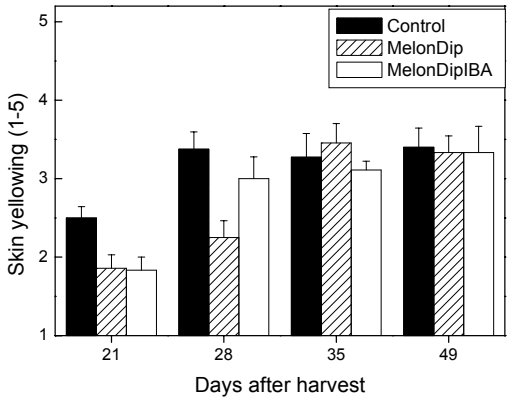
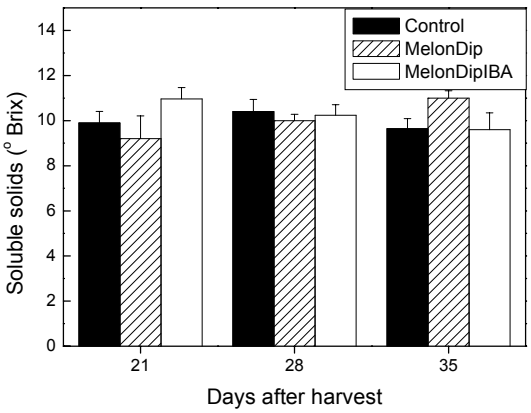
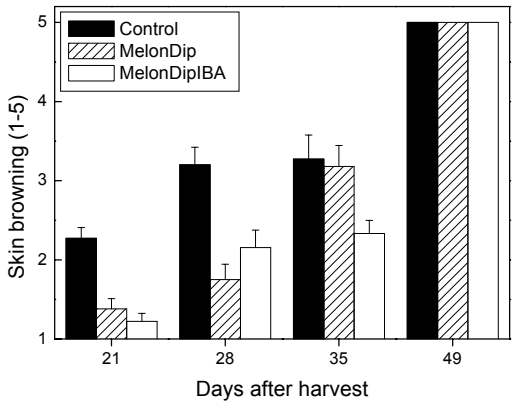
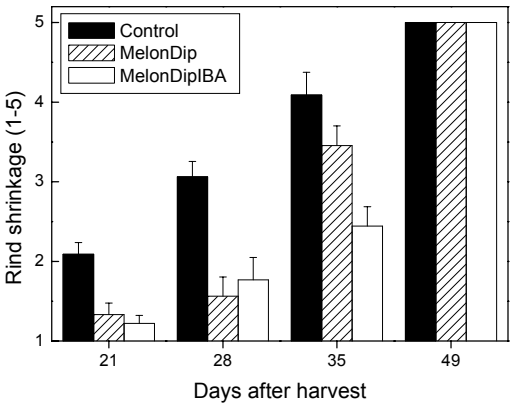


Figure 1. External skin rating (A), Internal flesh rating (B) and Flesh Firmness (C) on rockmelons treated with Melon dip (closed circles) or water (open circles)









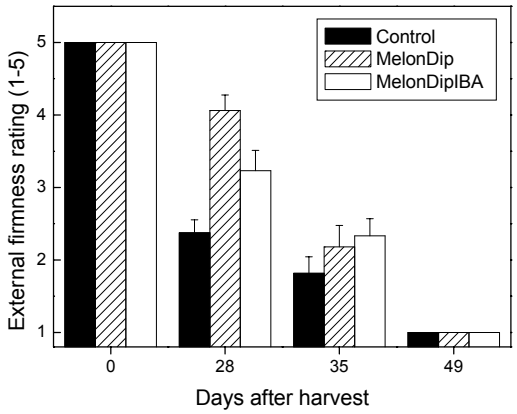


Figure 2. Skin yellowing, Skin browning, external firmness, soluble solids and rind shrinkage of rockmelon fruit treated with melon Dip, melon dip plus IBA or water (control).

Photo 1. Control Fruit 28 Days after harvest

Photo 2. Calcium treated fruit 28 days after harvest

Photo 3. Calcium + IBA 28 days after harvest

8. Rockmelon Soluble Solids Testing throughout 2004 from Flemington Markets, Sydney.

Introduction

In 1999, a survey of rockmelon fruit grown in Queensland showed 50% of the rockmelon fruit had a SSC of 8.7% or less and virtually no of the fruit were above 10% SSC (K. Walsh pers. comm.).

As part of a melon industry initiative in 2003, AHR agreed to collect fruit SSC data from fruit sold on the Sydney market every fortnight, for the whole of 2004. The aim of this work was to:

1. Collect baseline data on the average SSC levels in fruit consumers are currently buying, and

2. Try and shift some focus onto quality, rather than just size and external appearance.

There has been some criticism that SSC only partly describes fruit eating quality in rockmelons quality, however SSC is a simple test to carry out compared to measuring volatile compounds (the other main flavour component) which requires expensive laboratory equipment and facilities.

Quality sensory evaluation data is also required to answer the two important questions: Is SSC a good indicator of rockmelons (and honeydew) eating quality; and, If so, at what level of SSC do consumers regard as a “good eating experience”.

SSC Variability in Rockmelon Fruit: There is a wide variation in the SSC level in a rockmelon fruit. Most of the variation occurs from outer to inner flesh and the soluble solids commonly varies by up to 7-8 ^{o} SSC across the fruit flesh. Leigh Barker (QDPI) has measured this variation in rockmelon SSC across fruit and his results show this variability very clearly in Fig. 1.

This variability of SSC in fruit raises the critical issue of where a fruit sample should be taken if you want to get a result that is both repeatable and representative of the eating experience?

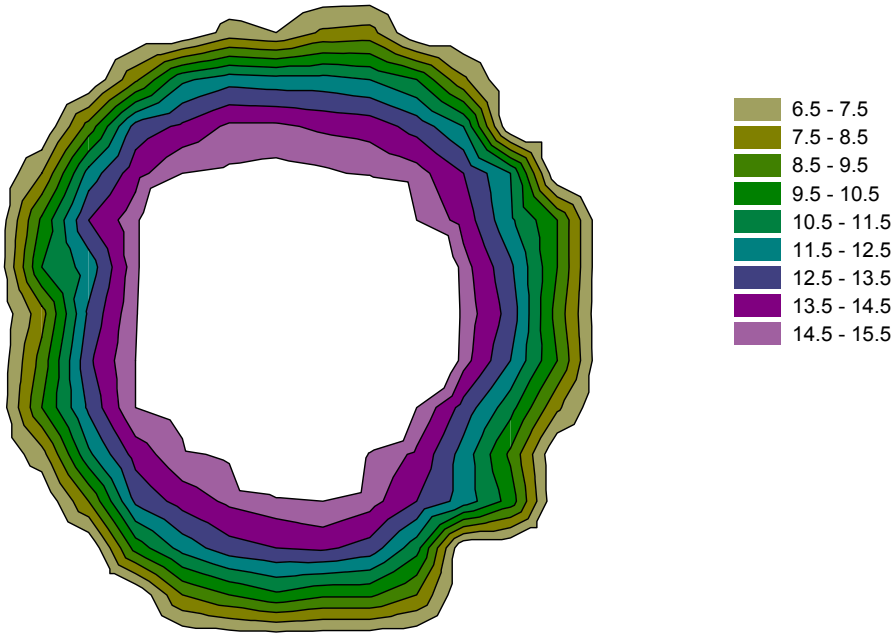


Figure 1. Distribution of SSC levels in Rockmelon Fruit (courtesy Leigh Barker, QDPI).

Materials and methods

Between 5 and 7 trays or bushel cartons, of rockmelons were sampled from the Sydney Market each fortnight. The fruit was generally selected from collaborating agents: Perfection Fresh, Tristate, Col Johnson, Action Fruit Supply, Sunfresh and Coles. Occasionally, additional trays were purchased off the market.

Three different SSC testing methods were used in the study. Each piece of fruit sampled in the study had the SSC measured by all methods. These methods were:

- **Whole flesh** – Cores were taken from either side of the fruit around the midline. The skin and seed were trimmed off the outer edge of the core, and the seed cavity remnants were removed from the inner section of the core. Both cores are then crushed, and the SSC of the whole sample measured using a refractometer.

- **Slice test** – A slice of the fruit was taken from the stem end to the flower end. The seed remnants were cut off and the juice squeezed on to a

refractometer and the SSC measured. This method is commonly used by QA for Woolworths, Coles.

- **Scratch test** – The fruit and measure the SSC of the juice from around seed measured by wiping this onto a refractometer. This is the method growers, agents and buyers.

Of the three testing method used, the whole flesh method is the one gives the closest estimate of what consumers are eating but it is very time consuming. The *scratch* and *slice* tests are much easier to carry out. The SSC levels found using the *scratch* test and the *slice* test were then plotted against the *whole flesh* method to give an indication of which method was most closely correlated with the whole flesh test.

Results and Discussion

SSC testing method comparison: The *slice* method gave a better estimate of whole fruit SSC than the scratch method, but both gave a SSC level that was actually higher than the *whole flesh* method (Figure 2).

The *scratch* test gave the highest SSC reading, and it's this test that most growers and agents currently use. The problem is that the method only samples the juice from the seed cavity which is the sweetest part of the fruit. The *scratch* result can be almost 5% SSC higher than the whole flesh result, and usually at least 2% SSC higher. The comparison between SSC levels found using the three methods are shown in Table 1. A *whole flesh* SSC of 10 is equivalent to a *scratch* test SSC of 12.2 and a *slice* test SSC of 11.0 (Table 1).

Table 1. Comparison between Rockmelon Fruit SSC Measured by the Whole Flesh, Slice and Scratch methods.

Whole Flesh	Slice Test Result	Scratch Test Result
7	7.0	8.0
8	8.4	9.4
9	9.7	10.8
10	11.0	12.2
11	12.4	13.7
12	13.7	15.1
13	15.0	16.5
14	16.4	18.0
15	17.7	19.4
16	19.0	20.8

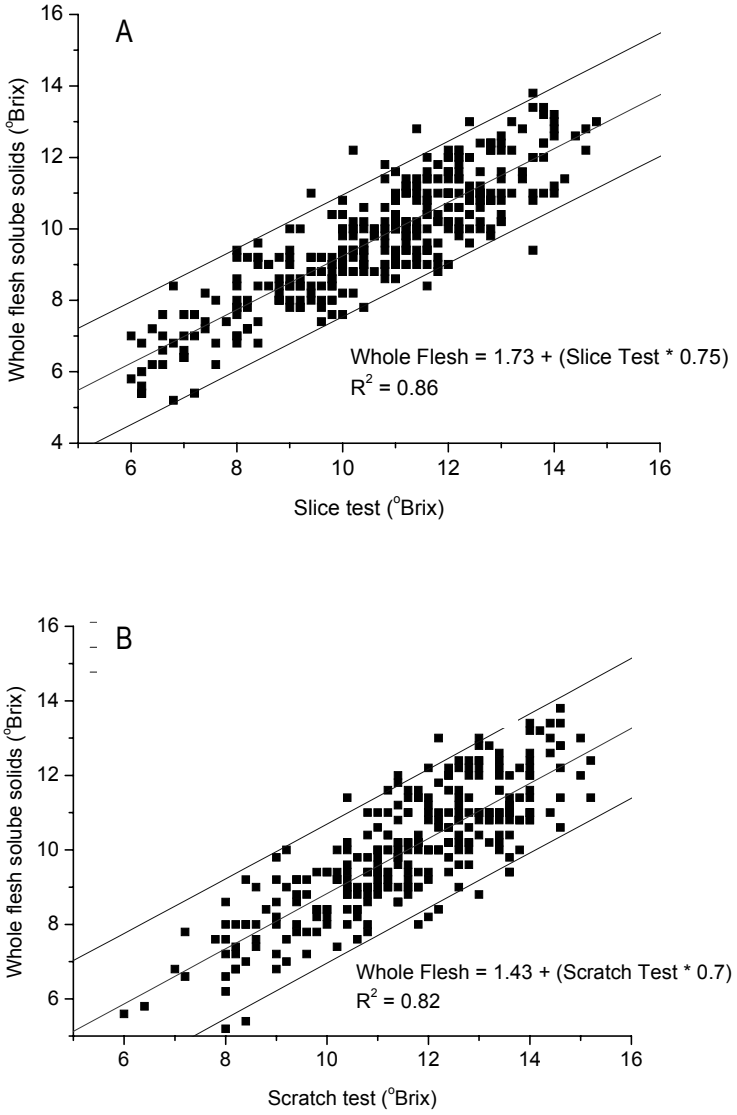


Figure 2. Comparison between rockmelon SSC measured using the Slice method (A) and the Scratch Method (B) compared to the whole flesh SSC. The lines indicate the mean, upper and lower confidence limits (P<0.95) of the data.

It would be possible to measure SSC using the Slice method which is quick and easy to do, and convert the result to the equivalent whole flesh which better represents the consumer eating experience, using table 1.

Results of the Sydney Market Survey: The average soluble solids, measured by the *whole flesh* method was 9.8 % SSC on average over the year, with individual fruit ranging from between 5.2 and 15.2 %. There were clear trends in fruit SSC levels over the year. The sweetest fruit on the market was around late February to early March, and then again from late September through to December.

The poorest fruit was on the market around May to June. SSC levels rose in July to about 10, then fell again in August. Over the year 46% of the fruit sampled were below 10 ^{o} SSC using the whole flesh method. Average SSC levels using the slice method were 10.7 and 11.6 using the Scratch test method.

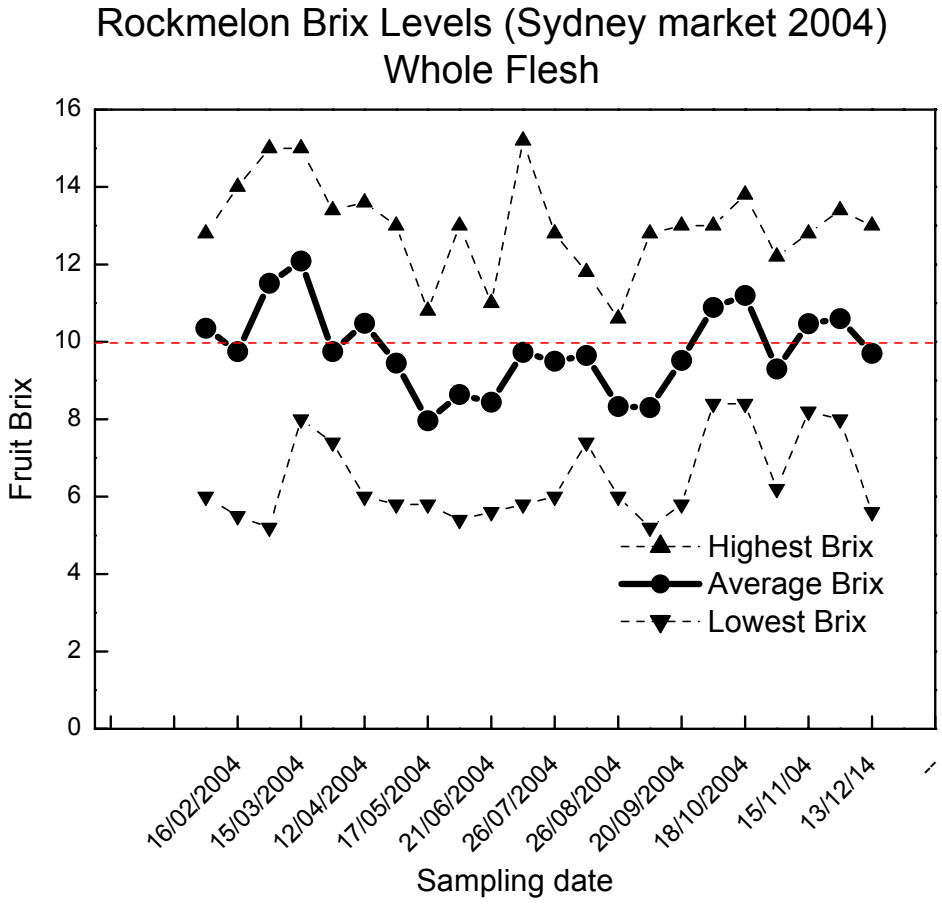


Figure 3 Results of the Sydney Market Rockmelon SSC Survey, 2004.

The SSC of fruit on the Sydney market was 9.8 % SSC on average over 2004, with individual fruit ranging from 5.2 to 5.2 %. There were clear trends in fruit SSC levels over the year with the sweetest fruit on the market was around late February to early March, and then again from late September through to December. The *slice* testing method gave a better estimate of whole fruit SSC than the scratch method, but both gave a SSC level that was actually higher than the *whole flesh* method. A *whole flesh* SSC of 10% is equivalent to a *scratch* test SSC of 12.2% and a *slice* test SSC of 11.0% and a table was presented to for conversions.

9. Conclusions

The project investigated soil moisture, nutrition and source-sink manipulation techniques and varieties in an attempt to determine an agronomic approach to producing high SSC rockmelons.

The key finings were used as the basis for writing agronomic guidelines for the production of high SSC rockmelons. These guidelines are presented as a separate document.

Varieties: For the winter production regions, the best varieties were: ACX 9201, 437-2, YRM 3628 and RM 1147, 849 and Mel 9409 and Hotshot. For either the spring → summer transition ort the summer → autumn transition, the best varieties were: 437-2, YRM 3628, RM 1147, RM 1143, JTRM 820, 5801, JTRM 815, RM 1246, RM 1150, RM 1144, 849, RM 1155, RZ001, RM 1260, Mel 9409, 440-2, RM 1139 and Dubloon.

Crop load control: Fruit thinning in the final two to three weeks before harvest gave the greatest increase in fruit SSC but also resulted in a decrease in overall yield. Plant density could be increased to maintain 'normal' yields of fruit, although it was anticipated that increased plant density could cause a light limitation in the crop, reducing potential for assimilate supply to the fruit. Thinning could be viable if a premium is paid to the grower for high SSC fruit to compensate for reduced yield.

Irrigation: The common practice of allowing soil moisture to deplete close to and during harvest reduced fruit SSC and yield compared to keeping the plants free of water stress from flowering through to the end of harvest. This was likely to have been due to water stress during reducing assimilate supply to the fruit by slowing the rate of photosynthesis in the source leaves.

Nutrition: As a guide, nitrogen, phosphors and potassium should be applied at about 100, 30-50, 135 kg/ha respectively with about 75% of the N and K applied pre-plant and the balance applied later by fertigation. For N, the balance should be applied in the vegetative phase, and K should be applied during fruit development. The nutrient levels in the youngest fully expanded leaves should be used as guide to fertilizer rates on individual farms. New target tissue levels for managing crop nutrition are suggested.

Calcium Dipping of Fruit: Dipping fruit in a calcium solution and holding at 5 ^{o}C preserved external and internal fruit quality for up to 28 days after harvest compared to 14 days for undipped fruit. Adding IBA to the dip slightly delayed rind shrinkage over the effect of calcium alone. Fruit dipping is proposed as a viable commercial treatment to extend the shelf life of fruit.

Market survey and SSC testing method: The SSC of fruit on the Sydney market was 9.8 % SSC on average over 2004, with individual fruit ranging from 5.2 to 5.2 %. There were clear trends in fruit SSC levels over the year with the sweetest fruit on the market was around late February to early March, and then again from late September through to December. The *slice* testing method gave a better estimate of whole fruit SSC than the scratch method, but both gave a SSC level that was actually higher than the *whole flesh* method. A *whole flesh* SSC of 10% is equivalent to a *scratch* test SSC of 12.2% and a *slice* test SSC of 11.0% and a table was presented to for conversions.

10 Technology Transfer

Journal Articles (Refereed)

Lester, G. E. Jifon, J. L. & Rogers, G., 2004, 'Supplemental foliar potassium applications during muskmelon fruit development can improve fruit quality, ascorbic acid, and beta-carotene contents', *Journal of the American Society for Horticultural Science* **130,** 649-653.

Long, R.L., Walsh, K.B., Rogers, G.S., & Midmore, D.J., 2004, 'Source-sink manipulation to increase melon (*Cucumis melo* L.) fruit biomass and soluble sugar-content', *Australian Journal of Agricultural Research* **55**, 1214-1251.

Long, R.L., Walsh, K.B., Midmore, D.J. & Rogers, G.S., 2006 'Irrigation scheduling to increase muskmelon (Cucumis melo L.) fruit biomass and soluble solids concentration', HortScience (accepted).

Conference Proceedings (Refereed)

Long R.L., Walsh, K.B., Midmore, D.J., Rogers, G.S., (2002) NIR Estimation of Rockmelon (*Cucumis melo*) Fruit TDS, in Relation to Tissue Inhomogeneity. Proceedings of the 2nd International Symposium on Cucurbits Tokyo, Japan Acta Hort. 588 ISHS

Conference Proceedings (not refereed)

Rogers, G.S. (2002) Development of Crop Management Program to Improve the Sugar Content and Quality of Rockmelons. Proceedings of the Australian Melon Conference. Melbourne, Australia 25th-27th July Melon Runner Vol 13

Presentation at the Australian Society for Horticultural Science National Conference. Sydney, Sept 30-Oct3 2002.

Magazine Articles

Good Fruit and Vegetables:

2004, 'The Australian melon Industry: making Progress. Mention of the agronomic and market SSC testing work', *Good Fruit and Vegetables* **15:1**, 27-28

2004, 'Agronomy to improve rockmelon eating quality', *Good Fruit and Vegetables* **15:2**, 47

2004, ‘Melon industry reviews strategies. Mention of agronomic, market SSC testing work and technology transfer to growers at regional meetings’, *Good Fruit and Vegetables* **15:6**, 53

2004, ‘Growing sweeter rockmelons’, *Good Fruit and Vegetables* **15:6**, 64-6*5*

2005, ‘Sweet success for rockmelon crop management’, *Good Fruit and Vegetables* **16:6**, 31-32

Melon News

Rogers, G.S., 2004, ‘Production of Sweet Rockmelons’, *Melon News* **18**, 2

Rogers, G.S., 2004, ‘Melon farmers thrilled with Bourke Field Day’, GRS *Melon News* **18**, 7

2004, ‘Meeting Reports – No fools at Mildura Field Day’, *Melon News* **19**, 3

2004, ‘Update on Melon Industry Projects – Melon SSC Monitoring in the Sydney Markets., Field Days (Bourke & Mildura)’, *Melon News* **19**, 6

Rogers, G.S., 2004, ‘Rockmelon SSC Testing on the Sydney Market’, *Melon News* **20,** 4

2004, ‘Rockmelon SSC Monitoring Project’, *Australian Melon Runner* **18**, 4

2004, ‘Variability in Rockmelon SSC results highlights need for Industry Standards’, *Australian Melon Runner* **18**, 5

2004, ‘Development of Crop Management Program to Improve the Sugar-Content and Quality of Rockmelons’, *Australian Melon Runner* **18**, 9-11

September 2004. Mention of agronomic and market SSC testing work

Presentations

Dr. Gordon Rogers presented ‘Rockmelon NIRS and agronomic programme’ to USDA-ARS Staff at Weslaco, Texas, USA. on Wednesday, 12th June, 2002,

Dr. Gordon Rogers presented to USDA-ARS staff at Lane Research Centre, Lane Oklahoma, USA On Friday 14th June, 2002

Dr. Gordon Rogers presented ‘Development of Crop Management Program to improve the sugar content and quality of Rockmelons’, to the AuSHS meeting 2nd September 2004

Dr. Gordon Rogers presented calcium dipping results at the US Ag Associates meeting to US industry members . Houston, Texas. January 2005)

Invitation to speak at the Processing Tomato Conference in Echuca 27th May, 2004 on the rockmelon agronomic project in conjunction with Dr Doris Blasseing (ServAg) on a tomato soluble solids project.

Rockmelon Agronomy - Sydney Market SSC Testing and Bourke Trial Update - July 2004

Field days

NIRS launch at Back O Bourke Fruits, Bourke, NSW, Wednesday 10th April, 2002.
AHR prepared posters which were placed alongside field plots and discussed trials with visitors in the field. Article in Good Fruit and Vegetables June 2002 p.45.

Field day - Douglas Daly, NT . August 2003.

Field Day – Back O Burke Fruits, Bourke, NSW. 15th of January 2004.
Around 40 people attended of which half the attendees were growers The day included introductory talks from Phillip Mansell (Back O Bourke Fruits); Henrik Christiansen (Harvest Company); Emily Martin (Melon IDO) and Gordon Rogers (AHR). A tour of the packing shed followed with demonstration of the Near Infrared sorting technology and tasting of fruit pulled from the packing line.

A field walk followed with demonstrations of AHR irrigation trials and a comparison between direct seeded and transplanted crops. Fruit was tasted from an area irrigated throughout the harvest period and compared to fruit taken from an area where irrigation had been turned off prior to harvest. Growers were also given the opportunity to view the differences in root systems of transplanted and direct seeded crops with the importance of a healthy root system emphasised.

All attendees received a 30 page handbook entitled Rockmelon Agronomic Guidelines" which has been developed throughout this project.

The field day was made possible thanks to HAL, The Harvest Company, Applied Horticultural Research, Central Qld. University and Back O Bourke Fruits.

Field Day – Thurla Farms, Mildura, NSW. 1st April 2004:

Around 80 people attended of which half the attendees were growers. The day included introductory talks Rob Wheatley (Thurla farms); Henrik Christiansen, Ed

Thistlewaite and James Corneliusen (Harvest Company); Jo Embry (Melon IDO) and Gordon Rogers (AHR). A tour of the packing shed followed with demonstration of the Near Infrared sorting technology and tasting of fruit pulled from the packing line.

A field walk followed with demonstrations of AHR irrigation trials. Fruit was tasted from an area irrigated throughout the harvest period and compared to fruit taken from an area where irrigation had been turned off prior to harvest. Growers were also given the opportunity to view the differences in root systems of transplanted and direct seeded crops with the importance of a healthy root system emphasised.

All attendees received a 30 page handbook entitled Rockmelon Agronomic Guidelines" which has been developed throughout this project.

Field Day – Chinchilla: A field day was held at Chinchilla, on Fred Turner's property. This was organised by the Australian Melon Association and the Chinchilla Melon Festival committee. Dr Rogers presented the results of the Rockmelon agronomic project to growers and industry people at the field day.

All attendees received a 30 page handbook entitled Rockmelon Agronomic Guidelines" which has been developed throughout this project.

Rockmelon Agronomic Workshop September 2004 Brisbane

Presentations, Meetings, Seminars, Workshops and other Events

Farm visits: Gary Amaros, Griffith, NSW and Andrew Young, Robinvale, Vic.

Hosted a visit by Prof. Ray Martin, Professor and Department head, Purdue University, Indiana USA. Recognised expert on Melon Sudden Wilt, *Fusarium* and *Monosporascus*.

Visit to Sydney University for discussions Dr McConchie.

Visit to Gary Amaros, Griffith, and representative from NSW Agriculture, Yanco.

Visit to Andrew Young, Robinvale, Vic.

Attended the Melon Industry Strategic Planning Working Group in Brisbane, June 2003.

Attended the Melon Industry Working in Brisbane, 22nd August and discussed inclusion of trial results in the industry best practice manual.

Grower Meetings were held at Sydney airport with Back O Bourke Fruits and Darling Farms to explain to the trial results and the agronomic manual (June 2003).

Grower Meeting with Back O Bourke managers in Bourke 29-30th July, 2003.

Melon Best Practice meeting 20/10/03

Melon Best Practice meeting 20/11/03

Grower Meetings at Katherine and Kununurra. The meetings were well attended at both locations, and were held in co-operation with the Australian melon Association. Speakers included: Judy Greensill (Melon association president, Jo Embry and Emily Martin (Melon IDOs), Ed Thistlewaite (The Harvest Company). 2004

Grower Meetings were held in Katherine, NT Kununurra, WA, Cowra, NSW, Rockhampton, Qld, Bowen, Qld, Gumlu, Qld (Burdekin), Tully, Qld, Bundaberg, Qld and Griffith, NSW. Where major growers in each region did not attend the meetings, these growers and visited individually. 2004

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