CropSeed Confidential Report No. 147

Strategies for improving the sweetness of export buttercup squash

A report prepared for
The New Zealand Buttercup Squash Council Inc.

B L Bycroft, P L Hurst, R E Lill & V M Cheer
August 1994

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B L Bycroft, P L Hurst, R E Lill & V M Cheer

NZ BUTTERCUP SQUASH COUNCIL INC.

30 August 1994

Memo to: Executive Committee Members

Subject: **R&D Report- Strategies for Improving the Sweetness of Export Buttercup Squash**
by Bycroft, Hurst, Lill & Cheer, Crop & Food Research, Aug 1994

Attached is the report from Crop & Food Research: Strategies for Improving the Sweetness of Export Buttercup Squash.

This report outlines the results of one of the Council's 1993/94 R&D projects, refer minutes of 7 December 1993, page 7. Cost: $18,500. You have also had an earlier report relating to this subject, entitled "Sweetness and Colour of Buttercup Squash" April 1994, and sent to you on 9 May 1994.

Please come to Tuesday's meeting with your comments and questions.

Kind Regards

Liz Shaw
Assistant Product Group Manager

c.c. Dr Bill Jermyn, R&D Manager
Hans Verberne, Quality Manager
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1 EXECUTIVE SUMMARY

The taste of squash has been identified by the Squash Council as a priority area for research. Improving sweetness is seen as particularly important for the Japanese market. In three experiments during the 1993/94 season, we investigated strategies for raising the sweetness of export squash by increasing the conversion of starch to glucose, fructose and sucrose.

We tested two field management strategies:

1. Trimming the vines and limiting numbers of fruit per vine during the fruit expansion phase of growth ('Trimming experiment')

2. Spraying the vines with low concentrations of glyphosate in the weeks prior to harvest ('Accelerated senescence experiment').

We also tested a postharvest strategy in which squash from Levin and Hawke's Bay were stored at 3, 12 or 33°C for one week, prior to storage at 12°C ('Storage experiment').

Trimming the vegetative growth of the vines and limiting the number of fruit per vine had no effect on starch or sugar levels at harvest or after storage.

Spraying the vines with glyphosate also had no effect on starch or sugar levels.

High temperature (33°C) storage of harvested squash for one week significantly reduced starch content and significantly increased sucrose content. These trends continued during subsequent storage at 12°C for five weeks.

Further research is required to establish the time/temperature regime which best promotes conversion of starch to sucrose while minimising bronzing and weight loss.

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New Zealand Institute for Crop & Food Research Ltd

2 INTRODUCTION

Squash production in New Zealand is increasing and reached more than 95,000 tonnes in the 1993/94 year. As production increases, it will be important to improve quality of export squash to compete with squash from other countries, such as Mexico.

The taste of squash has been identified by the New Zealand Buttercup Squash Council as a priority area for research. In three experiments at Levin Research Centre, we investigated strategies to improve the taste of export squash by raising the sweetness of fruit before and after harvest.

In the first experiment, we limited vegetative growth, fruit load, or both. We thought that removing some vegetative growth and later-setting fruit would reduce competition with earlier-setting fruit for available carbohydrate reserves. This would allow an increased accumulation of starch and sugars in these earlier fruit.

In a second experiment, we sprayed glyphosate on the vines at a low concentration in the weeks prior to harvest. In Hawaii, preharvest sprays of glyphosate are used to raise the sucrose levels in sugar cane by stopping the growth of the cane tips and accelerating the senescence (maturation) of the canes. We wished to test whether a similar effect could be achieved with squash.

In a third experiment, we stored squash harvested in Hawke's Bay and at Levin Research Centre at 3, 12 or 33°C for one week and at 12°C for a further five weeks. Potatoes stored at low temperatures convert starch to sugars faster than when they are stored at ambient. In Japan, some harvested squash are stored in tunnel houses for short periods, prior to marketing. It is likely that this storage period is at a temperature higher than ambient and is designed to improve the flavour of the squash. Therefore, it appeared that both low and high storage temperatures could affect accumulation of starch and sugars.

3 METHODS

3.1 Trimming experiment

Squash were field-sown on 16 November, 1993 at Levin Research Centre, in randomised plots of 14 plants, at 600 mm spacing in the row, 2 m between rows. Plant growth was limited either by removing vegetative growth from the vines or removing set fruit from each vine, or combinations of these two treatments.

i. *Vine trimming*

   a. Trimming rows to 1.2 m wide (`1.2 m wide')

   b. Limiting the number of laterals to two per plant (`2 laterals')

   c. No trimming (`No trim')

ii. *Fruit removal*

   a. Limiting the number of fruit to one per vine (`One fruit')

   b. Not limiting the number of fruit per vine (`Full fruit')

Weed control was by mechanical means, either push-hoeing or with a `speed-weeder' tractor-mounted cultivator. Sulphur was sprayed on the crop at the beginning of March 1994 to control powdery mildew.

The crop was harvested on 22 March, 1994. All fruit were weighed and graded either `export' if they weighed more than 1.3 kg, were mature and the skin had few blemishes, or `reject' if any of the export criteria were not met.

Twelve export grade fruit were selected from each treatment. Half of these fruit were immediately analyzed for firmness and flesh colour. Flesh samples were frozen for later analysis of dry matter and carbohydrate contents.

Remaining selected fruit were stored at 12°C for 6 weeks at Levin Research Centre, to simulate transport to the Japanese market. These squash were then reweighed and assessed for firmness, colour, dry matter and carbohydrate contents.

3.2 Accelerated senescence experiment

Squash were grown as described above, except that the vines were not trimmed and no sulphur was applied.

In a preliminary field experiment, we sprayed a range of concentrations of glyphosate (`Roundup´) on small plots of squash plants. From the results, we chose a rate of 0.1%, which caused yellowing of the running tips of the vines within 10 days, suggesting translocation of the chemical to the growing tips.

Glyphosate was sprayed on the plots either four, two or one week before harvest. Further plots were left unsprayed.

The crop was harvested on 15 March, 1994. All fruit were weighed, graded and analyzed as in the trimming experiment.

3.3 Storage experiment

Export squash were collected from packhouses in Hawke's Bay on two occasions and harvested from the field at Levin Research Centre on two further occasions during the 1993/94 season. Fruit were randomly allocated to plots and six fruit per plot were either analyzed immediately, after storage at 3, 12 or 33°C for one week or after subsequent storage for five weeks at 12°C.

Fruit were analyzed for weight loss, firmness, and flesh and skin colour. Flesh samples were frozen for later analysis of dry matter and carbohydrate contents.

3.4 Measurements

In each experiment, we measured carbohydrate levels (starch, glucose, fructose, sucrose and total soluble sugar) in the fruit as indicators of sweetness. We also measured the effects of the treatments on weight loss, fruit yield and changes in unpeeled fruit firmness (using a motorised penetrometer), dry matter content and flesh colour (using a Minolta CR200 chromameter) during storage of the fruit. The L, a, b colour coordinate system was used to measure colour changes in the fruit. `L´ is a measure of colour intensity, between black and white, `a´ measures colour on a scale from green to red and `b´ measures colour on a scale from yellow to blue. The value of `a´ best represented changes in flesh colour but `L´ and `b´ best represented changes in skin colour.

4 RESULTS AND DISCUSSION

4.1 Trimming experiment

4.1.1 Carbohydrate analysis

Neither the trimming nor the fruit load treatments had a significant impact on mean starch levels at harvest, which varied between 525 and 572 mg/g dry weight (Figure 1). Furthermore, no significant differences were detected among the treatments for either glucose, fructose, sucrose or total sugar levels (Figure 2). Mean glucose and fructose levels within treatments were very similar. Their values varied from 38 to 62 mg/g dry weight among treatments. Sucrose increased by approximately 10% (from 109 to 122 mg/g dry weight) when fruit load was limited, but this increase was not statistically significant. Total sugar levels were variable, but no trend was discernable as a consequence of either the trimming or fruit load treatments.

4.1.2 Dry matter content

Mean dry matter content varied between 26.9 and 30.0% at harvest and reduced after storage at 12°C for 6 weeks to between 24.0 and 25.3% (Table 1). The trimming and fruit load treatments had little effect on dry matter content.

4.1.3 Flesh colour

Fruit flesh became significantly redder (as measured by `a´) in all treatments during storage. Despite variations in mean values of `a´ at harvest among treatments, no significant differences in flesh colour were detected due to either the trimming or fruit load strategies (Table 1).

4.1.4 Fruit firmness

Fruit firmness changed little during storage at 12°C, with only a small increase from a mean of 7.05 kgf to 7.26 kgf. Differences among treatments were minor (Table 1).

4.1.5 Weight loss

Mean weight loss during storage varied between 3.9 and 4.8% for the various treatments (Table 1), but there was no significant difference among the treatments.

4.1.6 Yield

Trimming the vines (`2 laterals´ and `1.2 metres´) increased the number of export fruit per plot by 60% ($P < 0.03$) and doubled the total export yield compared to the `Full fruit, no trim´ control ($P < 0.04$) (Figures 3 and 4). The mean weight of individual

Figure 1: Starch at harvest for trimming experiment.

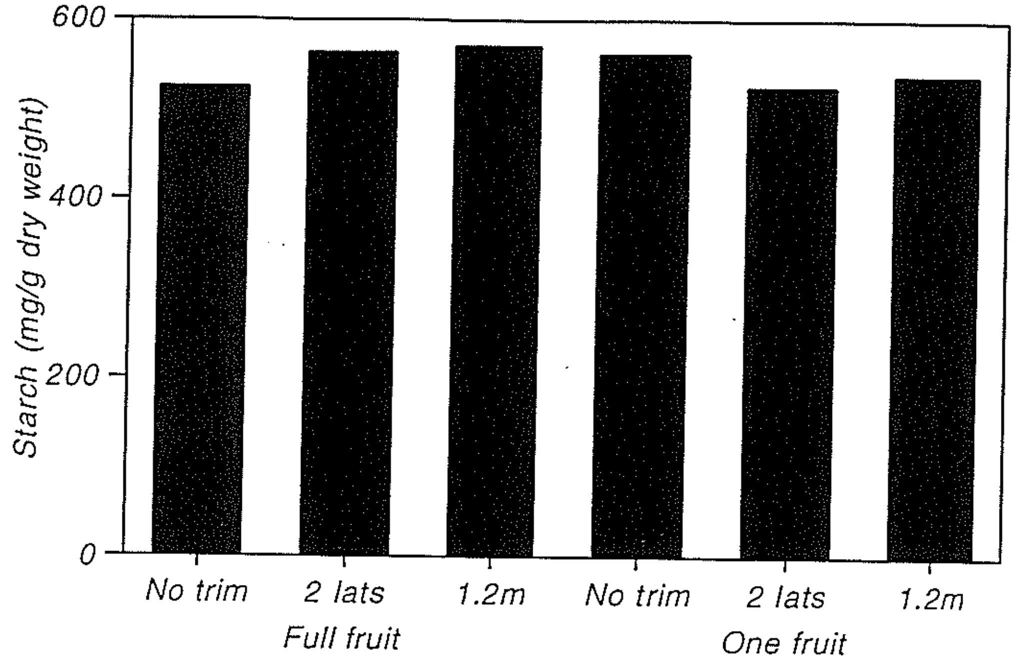


Figure 2: Sugar levels after 5 weeks of storage.

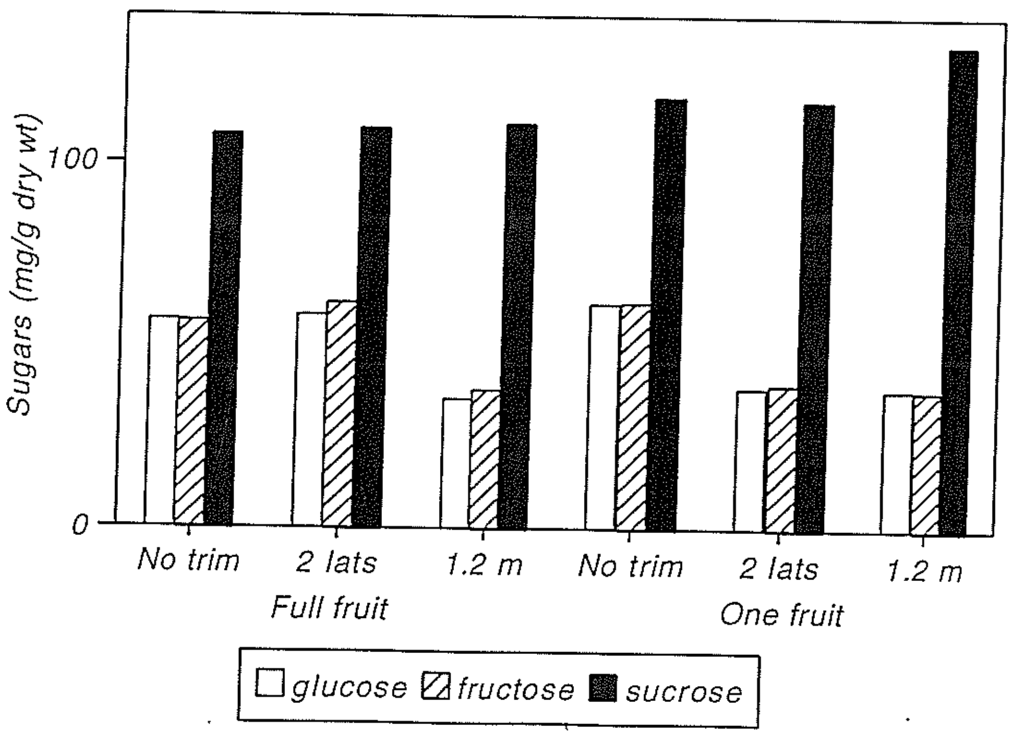


Table 1: Mean dry matter content, flesh colour, fruit firmness and weight loss for trimming experiment. Figures in column `(i)´ represent means at harvest and figures in column `(ii)´ represent means after 6 weeks storage at 12°C.

Treatment	Dry matter content (%)		Flesh colour (`a´ value)		Fruit firmness (kgf)		Weight loss (%)
	(i)	(ii)	(i)	(ii)	(i)	(ii)	
Full fruit, no trim	27.2	24.7	5.3	14.6	7.1	7.2	4.1
Full fruit, 1.2 metres	29.3	25.3	8.1	14.3	7.0	7.4	4.7
Full fruit, 2 laterals	27.8	24.0	6.7	14.9	7.0	7.3	4.6
One fruit, no trim	30.4	24.8	7.8	14.4	7.1	7.2	4.7
One fruit, 1.2 metres	30.2	24.7	5.5	14.1	7.1	7.1	4.0
One fruit, 2 laterals	26.9	25.0	3.5	16.7	7.0	7.3	3.9

individual export fruit was also slightly higher than the control, but this increase was not statistically significant (Figure 5).

Caution is required when extrapolating yield estimates from small plots such as these to large production units.

4.2 Accelerated senescence experiment

4.2.1 Carbohydrate analysis

Starch levels at harvest were similar for all treatments. Glucose, fructose, sucrose and total sugars were variable at harvest, but there were no treatment-associated trends. (Figures 6 and 7). After 6 weeks storage at 12°C, glucose, fructose, sucrose and total sugar levels had increased for all treatments. However, glucose and fructose levels were slightly lower in the two week and four week treatments than the unsprayed and one week treatments. Sucrose levels remained unaffected by the application of glyphosate.

Figure 3: Number of export fruit for trimming experiment.

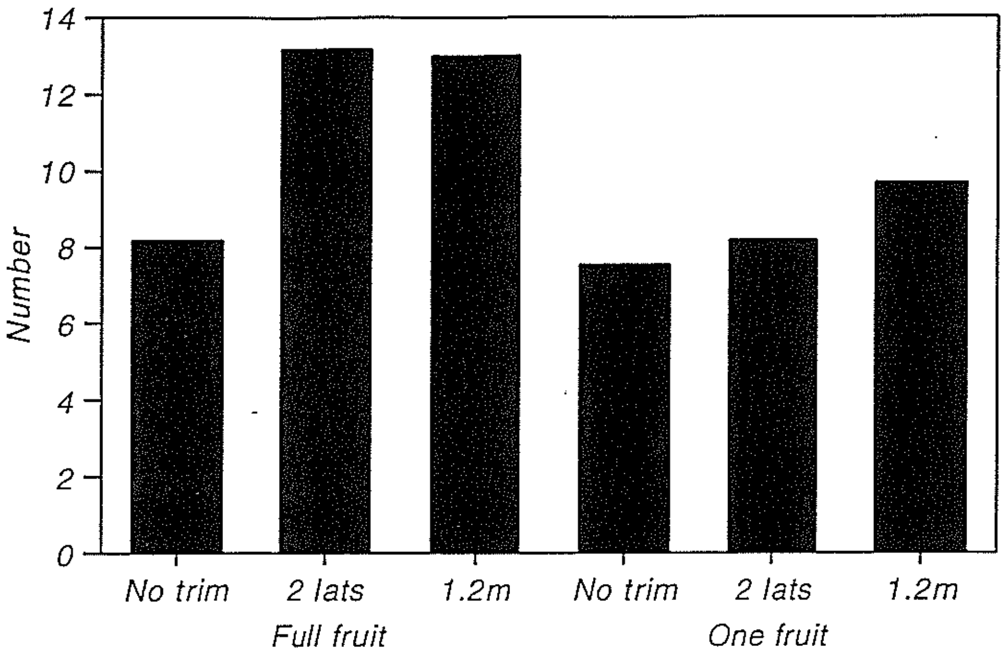


Figure 4: Weight of export fruit for trimming experiment.

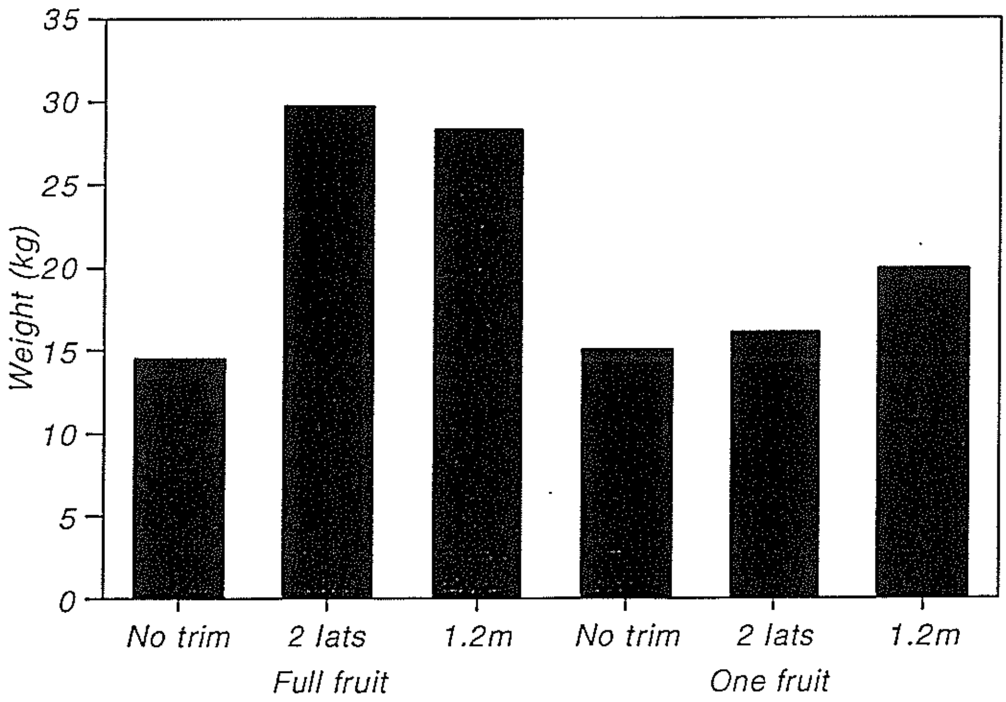


Figure 5: Mean weight of export fruit for trimming experiment.

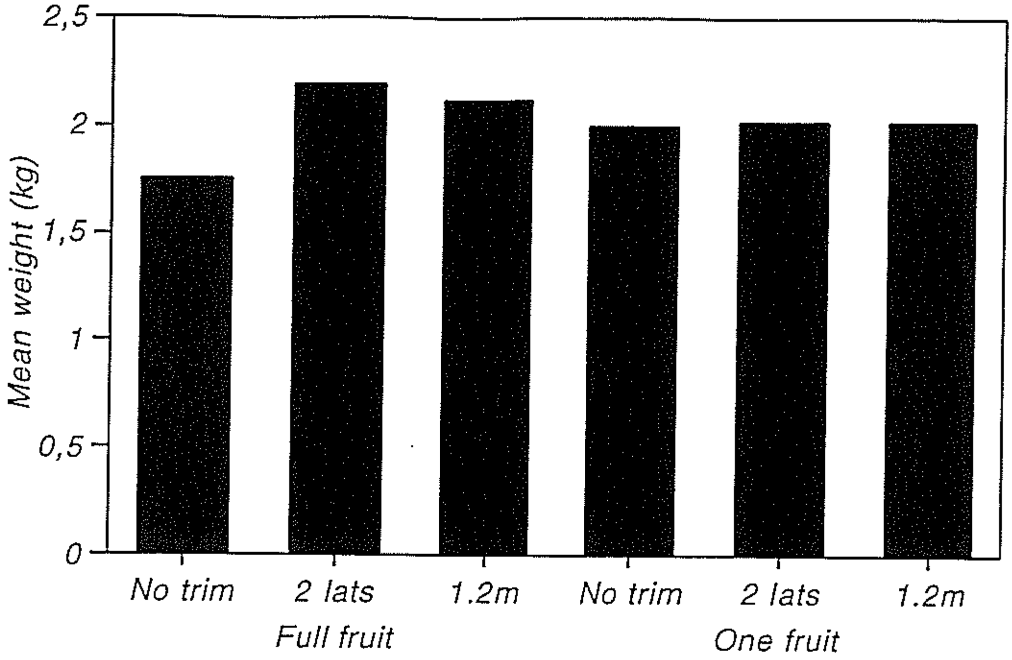


Figure 6: Starch at harvest for accelerated senescence experiment.

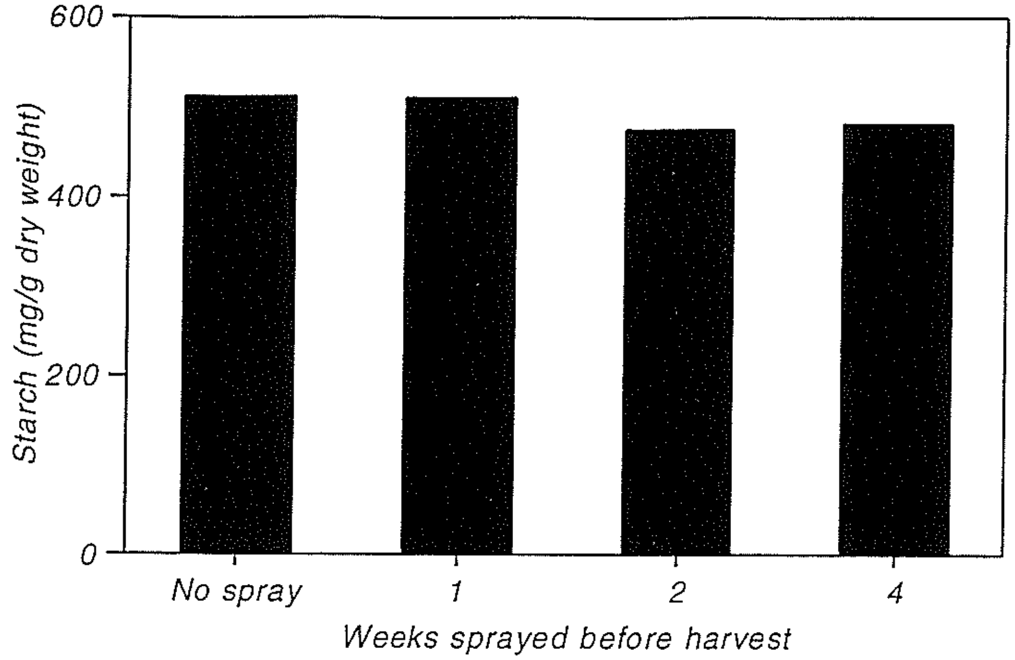
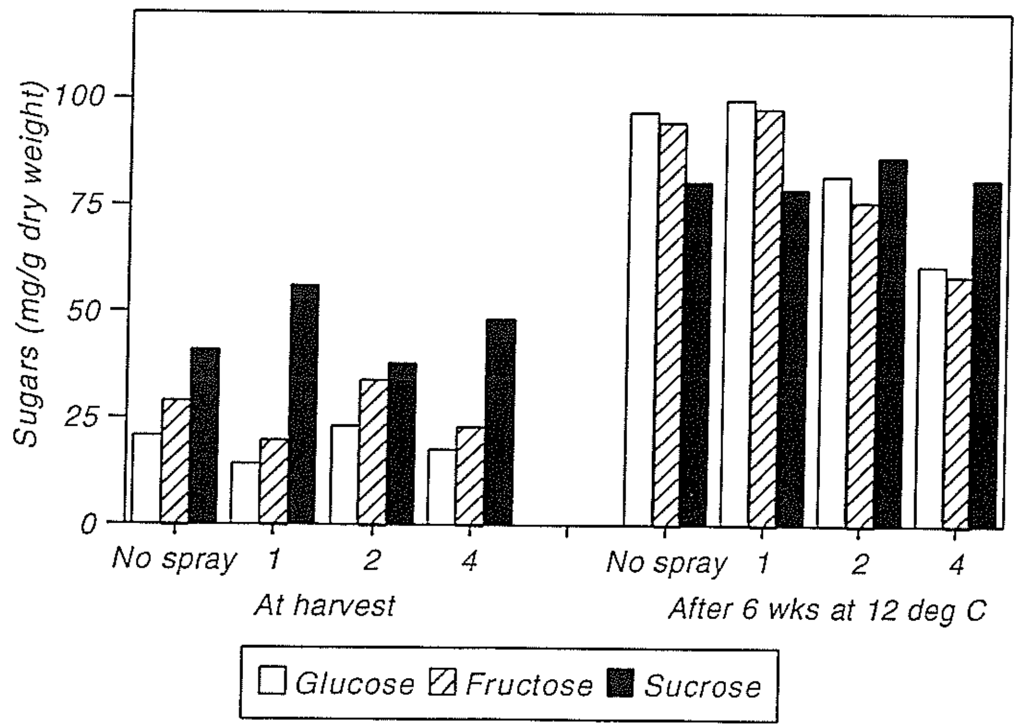


Figure 7: Sugars at harvest and after 6 weeks storage at 12°C.



4.2.2 *Dry matter content*

Dry matter content at harvest varied between 25.2 and 28.5% (Table 2). These levels reduced for all treatments after six weeks storage at 12°C to between 21.2 and 25.3%.

4.2.3 *Flesh colour*

Values of `a´ varied at harvest (Table 2). After storage, values increased to between 12.3 and 15.2. A trend of slightly increasing value of `a´ with increasing time between spraying and harvesting was evident, but this trend was not statistically significant.

4.2.4 *Flesh firmness*

Neither the treatments nor storage affected fruit firmness, with mean values varying between 7 kgf and 7.2 kgf (Table 2).

4.2.5 *Weight loss*

Weight loss during storage declined slightly with increasing time between treatment and harvest, however this difference was not statistically significant (Table 2).

Table 2: Mean dry matter content, flesh colour, fruit firmness and weight loss during storage for accelerated senescence experiment. Figures in column `(i)´ represent means at harvest and figures in column `(ii)´ represent means after 6 weeks storage at 12°C.

Weeks sprayed before harvest	Dry matter content (%)		Flesh colour (a value)		Fruit firmness (kgf)		Weight loss (%)
	(i)	(ii)	(i)	(ii)	(i)	(ii)	
No spray	26.9	21.4	3.2	12.4	7.0	7.0	4.1
1	28.5	21.2	5.4	12.3	7.2	7.0	3.9
2	25.2	23.9	1.4	14.0	7.2	7.0	3.5
4	27.7	25.3	4.1	15.2	7.1	7.2	3.4

4.2.6 *Yield*

Yield data for export fruit are shown in Table 3. The mean weight of individual export fruit was unaffected by the spray treatments. The mean number and total weight of export fruit appears to have increased as the time between spraying and harvest increased. However, there was no statistically significant difference between the treatments. Furthermore, it appears unlikely that the number of export squash would increase as a result of such treatments after fruit set is largely complete. No significant level of abortion of developed fruit was noted during the experiment.

As with the trimming experiment, caution is required when extrapolating yield estimates from small plots such as these to large production units.

Table 3: Export yield data for accelerated senescence experiment.

Weeks sprayed before harvest	Number of fruit	Total weight of fruit (kg)	Mean weight of fruit (kg)
No spray	7.2	13.2	1.81
1	8.0	15.9	1.88
2	8.7	16.7	1.91
4	10.8	23.0	1.99

4.3 Storage experiment

4.3.1 *Carbohydrate analysis*

Mean starch levels after one week's storage at each of the three temperatures varied between 322 mg/g dry weight for 33°C and 514 mg/g dry weight at 3°C (Figure 8). The mean level at harvest was 476 mg/g dry weight. The starch level after one week at 33°C was significantly lower than the levels at harvest, and after one week at 3°C and 12°C.

After one week of storage at 33°C, the mean sucrose level was 250% higher than that after one week of storage at 12°C (Figure 9). This difference increased to 280% after a further five weeks at 12°C.

After one week of storage at 3°C, sucrose levels were 30% higher than for those squash stored at 12°C. However, this difference was not apparent after a further 5 weeks storage at 12°C.

Glucose and fructose levels were similar in the squash stored at 3°C and at 12°C, but fructose was lower than glucose when squash were stored at 33°C. This difference was maintained after a further five weeks at 12°C.

Total sugars increased with increasing storage temperature and time. Levels of approximately 300 mg/g dry weight were reached after storage at 3 and 12°C and a further five weeks at 12°C. Squash stored at 33°C obtained total sugar levels of over 450 mg/g dry weight after subsequent storage at 12°C, a 50% increase over the lower temperature treatments.

4.3.2 *Dry matter content*

The mean dry matter content declined by 2.3% when squash were stored at 12°C for one week, but not when they were stored at 3°C or 33°C for one week (Table 4). However, the mean dry matter content of all squash declined by between 1.3 and 2.5% after subsequent storage at 12°C for five weeks.

4.3.3 *Colour*

Flesh colour as measured by `a´ increased during one week at 33°C, indicating a shift to the red end of the red-green scale (Table 4). The `a´ value increased significantly, regardless of initial treatment temperatures, during subsequent storage at 12°C for five weeks.

The `L´ and `b´ values of the L, a, b colour scale were used to measure differences in skin colour. The fruit stored at 33°C for one week and 12°C for five weeks were significantly lighter ($P < 0.06$) and more yellow ($P < 0.07$) in colour than the fruit stored at 12°C for five weeks after treatment at 3 or 12°C. This result confirms a visual assessment of these squash, which indicated more bronzing of the fruit stored at 33°C.

4.3.4 *Firmness*

Firmness declined during the first week and then increased after subsequent storage at 12°C, for all initial storage temperatures (Table 4). No differences in firmness were noted between temperatures.

4.3.5 *Weight loss*

Mean weight loss after one week of storage was highest for the squash stored at 33°C (Table 4). This pattern continued after 5 weeks of subsequent storage at 12°C.

Figure 8: Starch levels at harvest and after one week at each storage temperature.

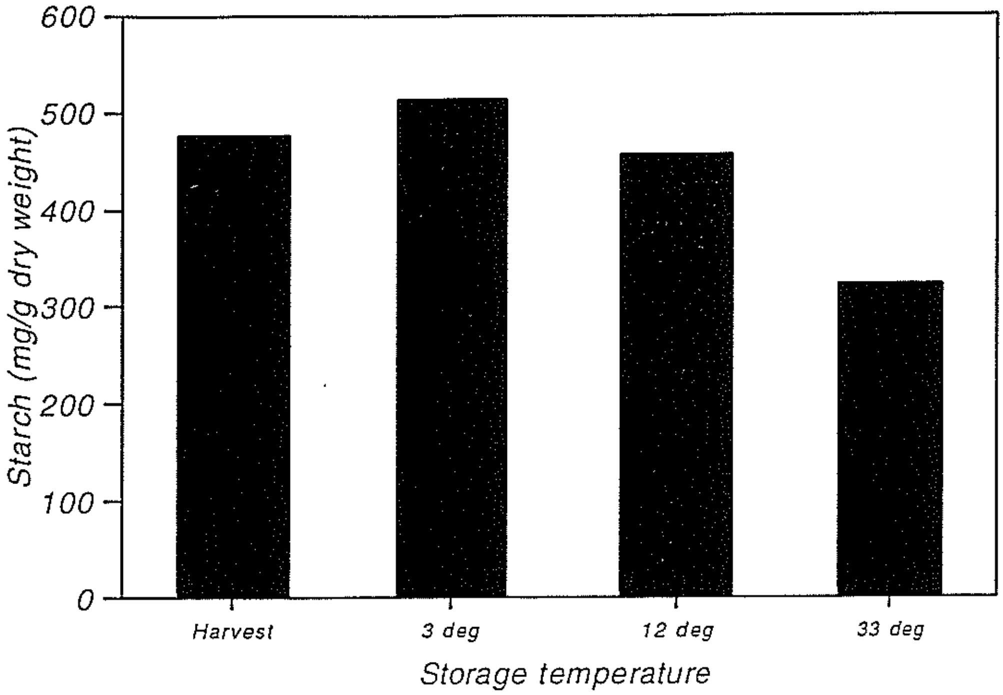


Figure 9: Sugar levels at harvest, after one week at each storage temperature and after a further 5 weeks at 12°C.

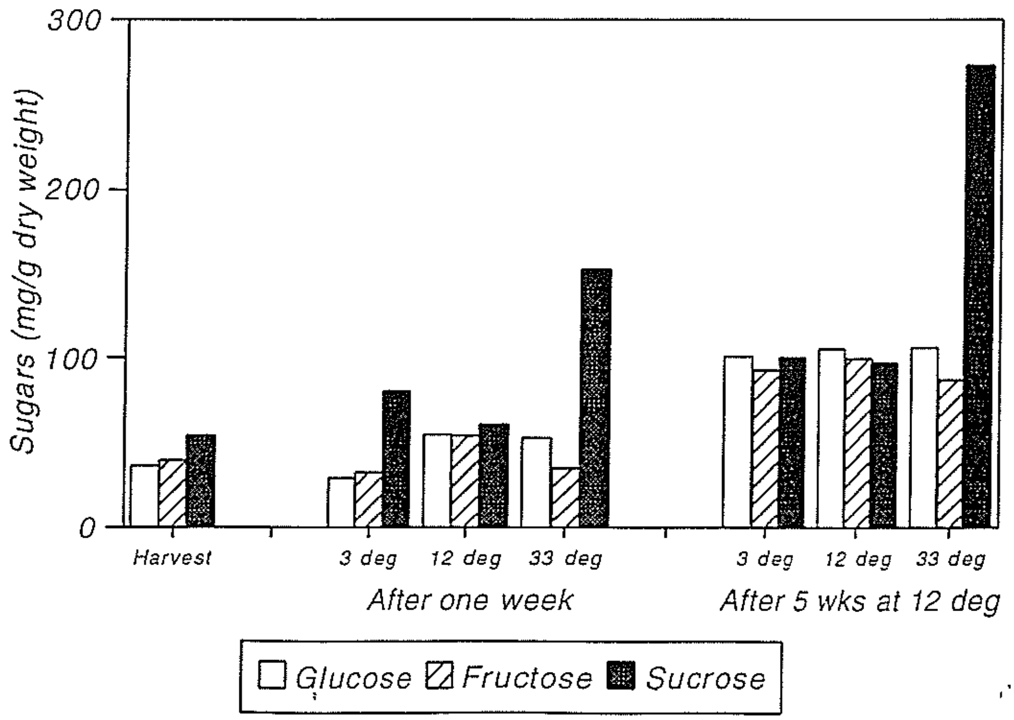


Table 4: Mean dry matter content, flesh and skin colour, fruit firmness and weight loss for storage experiment.

Treatment	Dry matter content (%)	Colour			Firmness (kgf)	Weight loss (%)
		Flesh	Skin			
		\`a´	\`L´	\`b´		
At harvest	27.9	3.4	-	-	7.1	-
3°C, 1 week	28.3	4.2	-	-	6.6	0.7
12°C, 1 week	25.6	5.1	-	-	6.4	1.5
33°C, 1 week	27.6	9.6	-	-	6.2	7.5
3°C, 1 wk & 12°C, 5 wks	25.8	15.0	31.7	10.1	7.0	4.8
12°C, 6 weeks	24.0	14.0	30.6	8.0	7.2	5.2
33°C, 1 wk & 12°C, 5 wks	26.3	15.8	36.5	15.4	6.9	9.6

5 CONCLUSIONS

The trimming regimes used in our experiments had little impact on the levels of starch after harvest, or soluble sugars after six weeks of storage of squash. Neither were the dry matter content, flesh colour, firmness or weight loss during storage at 12°C affected by the trimming treatments.

Trimming the vines by limiting the width of the vegetative growth or removing laterals may increase the number of export fruit harvested without affecting mean weight. This conclusion requires validation in larger scale field trials before it could be recommended for commercial production.

Spraying squash vines with low concentrations of glyphosate prior to harvest had little effect on the rate of conversion of starch to soluble sugars during storage of the fruit, other than perhaps a slight decrease in glucose and fructose levels as the interval between spraying and harvest increased. Neither does the glyphosate appear to affect dry matter content, flesh colour, firmness or weight loss to any great extent. No commercial application of this technology for squash production is apparent.

The results of the storage experiment suggest that starch is converted to sucrose in harvested squash more rapidly at high than low storage temperatures. The process involved in this conversion is not fully understood and is outside the brief of the current study. Nonetheless, it seems possible that the physiological changes which do occur could be exploited by packers and exporters in order to raise sucrose levels in squash for the Japanese market. Commercially harvested squash could be stored at elevated temperatures for short periods of time, prior to shipment.

Before commercial application could be recommended, further study is required to establish the temperature/time regime which will best increase sucrose content while minimising bronzing and weight loss. Sensory evaluation of the effect of high storage temperatures on the perceived sweetness and texture of squash would also be necessary. The cost of storing squash for short periods at, say 25 to 30°C, must also be weighed against the benefits of this technology.

6 ACKNOWLEDGEMENTS

We thank Sandy Wright for statistical advice. We also thank Mr Alan Cadwallader of Baycrop Packing Ltd and John Bostock of the J M Bostock Packhouse for providing squash used in our experiments.