THE EFFECT OF COOLING TREATMENTS ON THE INCIDENCE OF TIP ROT IN ASPARAGUS SPEARS

A Report for the NZ Asparagus Council

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TABLE OF CONTENTS

1. SUMMARY

The effect of postharvest temperature management on the incidence of tip rot of asparagus spears (cv. New Zealand Beacon Syn 2) harvested at an early or and a late stage of the season was investigated. Spears were either hydrocooled, or passively or rapidly cooled with humidified air (95-98% RH) 6 hours after harvest. The effect of delays of 0, 2, 4, 8, 12 and 24 hours at ambient temperatures (16-18°C) prior to hydrocooling were also investigated. Spears were evaluated for tip rot, weight loss, visual quality and toughness after either short term (3 days) or long term (3 weeks) storage at 2°C and a period of shelf life at 20°C.

The average time for spears to reach within 1°C of the storage temperature was 6 minutes, 8 hours and 48 hours for the hydrocooled, rapidly cooled and passively cooled treatments, respectively. The temperature of the apical tissues decreased and increased more rapidly during cooling and warming, respectively, than other tissues of the spear.

Tip rot incidence was 2 - to 10-fold higher in spears that had been stored for 3 weeks compared to spears that had been stored for 3 days, although the incidence increased during shelf life more rapidly than during storage. After 3 weeks storage and 4 days shelf life, the incidence of tip rot was approximately 25 to 30%, irrespective of whether spears had been hydrocooled or cooled with high humidity air. Delays of up to 12 hours prior to hydrocooling after harvest did not affect the incidence of tip rot, although there was a trend for tip rot to increase with longer delays at ambient temperatures. A delay of 24 hours after harvest increased the incidence of tip rot in spears. The incidence of tip rot was not different between spears harvested during the early or late stage of the season.

Visual quality and spear toughness was not significantly affected by the method and rate of cooling. Although hydrocooled spears tended to have a fresher appearance and be more tender than air cooled spears after 3 days of storage, these differences were not present after long term storage. Furthermore, differences in visual quality and toughness of spears were not consistent between treatments. The visual quality and toughness of spears was influenced by delays prior to hydrocooling, and both these spear characteristics were different in spears hydrocooled after 24 hours compared to spears hydrocooled after 12 hours. Shorter delays had no significant effects, or effects were inconsistent.

It is concluded that the incidence of tip rot, and the visual quality and toughness, of asparagus spears is not affected by the rate and method of cooling or by delays of up to 12 hours at ambient temperatures prior to cooling after harvest. However, overall spear quality may be marginally higher, and weight loss significantly less, in spears that are hydrocooled than spears that are rapidly or passively air cooled. Spears should be hydrocooled or rapidly cooled within 4 to 12 hours of harvest. The incidence of tip rot does not appear to be strongly linked to the time of harvest within a season.

2. INTRODUCTION

Despite their perishable nature it is desirable to send asparagus spears to export markets by sea freight rather than by air freight because of the cost difference between sea and air freight. If New Zealand-grown asparagus is to be sent to export markets by sea, a postharvest life of at least 4 weeks is necessary. Although such a postharvest life can be achieved (Lill 1980), excessive deterioration in quality during transit has occurred in some sea shipments, and consequently most of the New Zealand export crop is airfreighted to the markets, and in particular to Japan. However, even in air shipments, the occurrence of a disorder termed tip rot has continued to undermine the postharvest life of asparagus.

Tip rot is characterised by the presence of a foul odour and the water-soaked appearance of bracts at the tip of the spear. The affected tissue usually collapses and is colonised by wound pathogens, such as Fusarium spp. At harvest, all bracts appear sound, but 5 to 10 days after harvest and following commercial grading, packing and storage at low temperatures, up to 80% of the spears may be affected. The disorder, which has not been noted in growing spears prior to harvest, increases rapidly once spears that have been coolstored for more than 1 week are removed from storage (Carpenter et al. 1988). No studies on the seasonal incidence of tip rot have been reported but industry sources (R. Wood, pers. comm.) claim that the incidence of tip rot is higher during the first half of the harvest season and during periods of cold, wet weather than during the second half and warm, dry periods of the season.

The cause of tip rot has not been identified. Fungal and bacterial micro-organisms have been found to be associated with the syndrome (Ramsay and Wiant 1946, Carpenter et al. 1988), but these are considered to be secondary infections rather than causal agents since known fungicides and bactericides were found to be ineffective in controlling tip rot (Carpenter et al. 1988). In the absence of evidence implicating microbial pathogens, Carpenter et al. (1988) have suggested that the disorder is a result of physiological deterioration and that it is primarily a handling and storage problem. Earlier Ramsey and Wiant (1941) had suggested the disorder was related to inadequate cooling and careless handling.

Some studies on the postharvest handling of New Zealand grown asparagus have been reported (Lill 1980; King et al. 1986; King et al. 1988). Although none of these studies include specific data on tip rot, they do indicate that the benefits to shelf life obtained by hydrocooling spears are only significant if cooling of spears is delayed more than 16 to 24 hours after harvest. Commercially, spears are routinely precooled within 16 hours of harvest but the actual time can vary from 2 to 16 hours. Moreover, the actual temperature to which spears are rapidly cooled can vary, and since asparagus spears are susceptible to chilling injury (Hardenburg et al. 1986), it is possible that rapid precooling of spears immediately after harvest may be a factor in predisposing spears to tip rot. An additional factor may be the method used to precool spears. Typically, spears are precooled either by hydrocooling or forced-air cooling methods. Hydrocooling is a considerably faster means of precooling spears.

The objective of the present study was to investigate the relationship, if any, between the method, rate and time of cooling after harvest and the incidence of tip rot and quality of asparagus spears harvested during the early or late period of the season.

3. MATERIALS AND METHODS

3.1 Harvesting and handling.

Spears (cultivar New Zealand Beacon Syn. 2) were harvested on 9 October (designated H1) and on 20 November, 1989 (designated H2) from a commercial block at Ngahinapouri, Hamilton. After transport to the packhouse, spears were washed, graded and packed to export standards. Whilst being cut to a length of 22 cm, spears were washed with chlorinated water (chlorine concentration 200mg/ml). Medium size spears (butt diameter between 15 and 20 mm) were packed into wooden boxes designed to hold approximately 5 kg of asparagus. From each box, 4 bundles of 10 spears were grouped together and weighed before they were reinserted into the middle of the box. Where appropriate, thermocouples were inserted into spears within each of 4 boxes for each cooling treatment. Once packed, lids were placed on the boxes and the boxes were stacked onto pallets. Spears were then either hydrocooled, forced-air cooled or cooled passively to approximately 2-3°C, before storage at 2 ±1°C, in a high humidity atmosphere (95-98% RH) for either 3 days or 3 weeks, and then removed to 20°C. After 1, 4 or 7 days at 20°C, weight loss and spear quality was assessed. For each cooling treatment, 4 boxes of asparagus were used as replicates.

3.2 Cooling treatments.

a. Hydrocooling. Each box of spears was completely immersed in iced-water (0°C) containing chlorine (200 mg/ml) for 10 minutes. Although boxes were completely submerged, they were allowed to rise and fall within the water to facilitate heat exchange. Spears were hydrocooled 6 hours after harvest except when the effect of a delay at ambient temperatures (16-18°C) was investigated. In this case, spears were hydrocooled within 20-30 minutes, 2, 4, 8, 12 and 24 hours of harvest.

b. Rapid cooling. Humidified air (95-98% RH) was forced through pallet loads of asparagus at a velocity of approximately $2m^3$ per second; ie. forced-air cooling.

c. Passive cooling. Boxes were placed in the same coolstore as that used for hydrocooling and rapid cooling, but at a location which was not directly in line with the airflow originating from the fans.

3.3 Temperature measurements.

The rates of cooling and temperature changes during storage were monitored using T-type thermocouples (2mm x 10m) connected to a Delta T Devices data logger which was equipped with an in-built reference junction thermistor. For each cooling treatment, two spears in each of four replicate boxes, were monitored. In two of the replicate boxes, thermocouples were inserted into the tip and butt regions of one of the spears, and into the middle region of the second spear. In the remaining 2 replicate boxes, thermocouples were inserted midway down and approximately into the centre of both of the spears in each box. Spears that had thermocouples inserted into them were placed near the centre of the boxes, or such that they were surrounded by an equal number of spears. The spear temperatures were logged at 1 minute intervals in the case where spears were hydrocooled, and at 10 minute intervals where spears were rapidly or passively air cooled. During subsequent coolstorage, and in transit and during shelf life at 20°C, temperatures were logged at 1 hour intervals. Other than when stated, the temperatures reported here refer to the temperature at the mid-region of the spear.

3.4 Assessments.

The incidence of rots was determined on each replicate bunch of spears and/or on additional bundles of 10 randomly chosen spears in each of the 4 boxes per treatment.

The overall visual quality of spears in each bundle was rated using the scale described by King et al. (1988):

1 = fresh

3 = slight wilt, very slight wrinkles on stem

5 = browning of stem bracts, more pronounced wilting

7 = soft rots starting to develop, some browning of spears, wilting and feathering of spears.

9 = extensive rotting and stem collapse, severe wilting and browning of spears.

A rating of 6 denotes the end of commercial shelf life (King et al. 1988).

Toughness of spears was determined using an Instron 4301 Universal Texture Analyser fitted with a shear blade and recording the force required to cut through the spear as described by Werner et al. (1963) and Wiley et al. (1956). The force required to transversely cut each spear at a point 6, 12 or 19 cm from the tip was recorded. In addition, for each cooling treatment, the force required to cut each spear at 4 cm intervals from the tip was recorded for 10 spears in each treatment.

The respiration and ethylene production rate of treated spears was determined on four replicate bundles of 10-15 randomly chosen spears, after both 3 days and 3 weeks of storage. Each bundle was held at 20°C in 5 litre jars, through which a humidified air stream was passed at a rate of 70 ml/min. The ethylene and carbon dioxide concentrations in the exhaust air was determined by a gas chromatograph and an infra red gas analyser, respectively.

3.5 Statistical analysis.

Differences between treatments and evaluation times were subjected to analysis of variance and pooled standard deviations were used to produce least significant differences (LSD) at the $p<0.05$ or $p<0.001$ level. Where no significant differences between cooling treatments occurred, treatments were combined and treated as replicates to test effects such as time of season.

4. RESULTS

The full complement of results encompassed three rates of cooling (including two different methods of cooling) and 6 delays prior to hydrocooling, for spears which had been harvested on two separate occasions and assessed on at least two occasions after two periods of storage. For clarity, only results typical of treatment effects are presented.

4.1 Effect of rate and method of cooling.

A differential rate of cooling was observed within individual spears. The tip cooled significantly faster than the mid and basal sections of the spear (Fig. 1). This differential rate was most apparent when spears were hydrocooled, although also occurred when spears were air-cooled (Appendix 1-B). When hydrocooled spears were removed from the iced-water, the temperature of the tip increased, or stayed the same, whereas the temperature of the basal tissues continued to decrease (Fig. 1, Appendix 1-D).

The differential response to temperature by tissues of the spear was also apparent when spears were warmed upon removal from storage. The temperature of the tip increased more rapidly than the temperature of the basal tissues of the spear (Fig. 2). The average time for the temperature of hydrocooled spears to reach within one degree of 2°C was 6 minutes (Fig. 1), whereas the average time for rapidly cooled spears was 8 hours (Fig. 3). The temperature of passively cooled spears reached 3°C after 23 hours, and the temperature of these spears never reached 2°C throughout the first 4 days after harvest (Fig. 3).

After 3 weeks of storage at 2°C and 4 days shelf life at 20°C, approximately 25-30% of the spears had developed tip rot symptoms, but there was no difference between spears that had been hydrocooled and those that had been either rapidly or passively cooled by air (Table 1.1).

Tip rot increased significantly after spears were removed from storage, irrespective of cooling treatment. However, the actual magnitude of the increase differed between treatments. A 6 to 10 fold increase in the incidence of tip rot during shelf life occurred in spears that had been hydrocooled, whereas a 2 to 3 fold increase occurred in air cooled spears.

Figure 1. Mean temperatures at the tip, middle and butt regions of asparagus spears hydrocooled in ice water (0°C) and subsequently held at 2°C. Results are for asparagus spears harvested in October (H1).

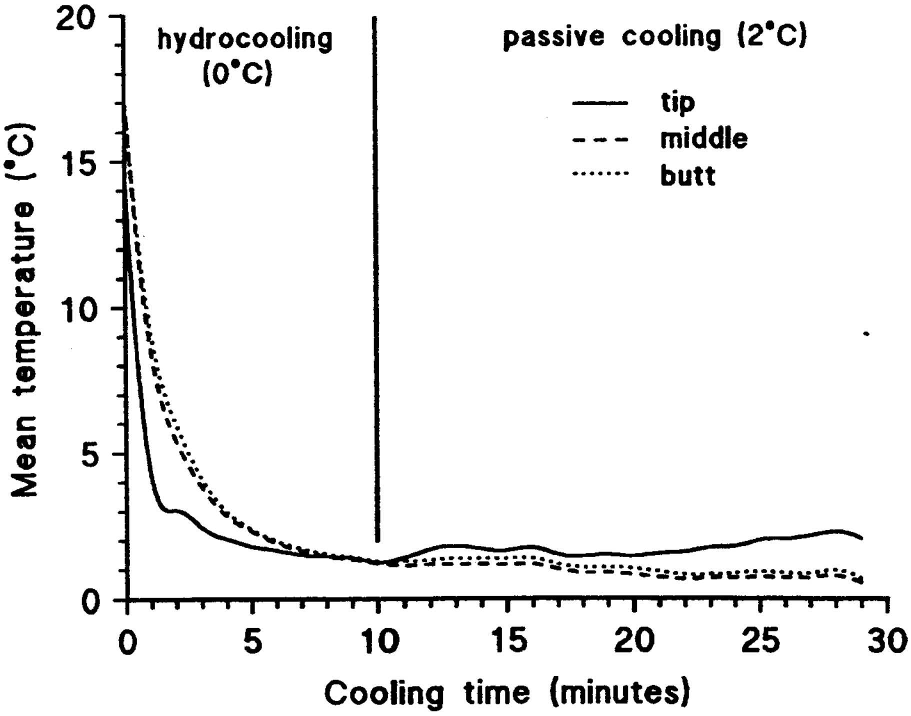

Figure 2. Changes in mean temperatures at tip, middle and butt regions of asparagus spears during passive air cooling and subsequent storage in a high humidity (95–98%) coolstore, and transport to Auckland before removal to 20°C. Results are for asparagus harvested in October (H1).

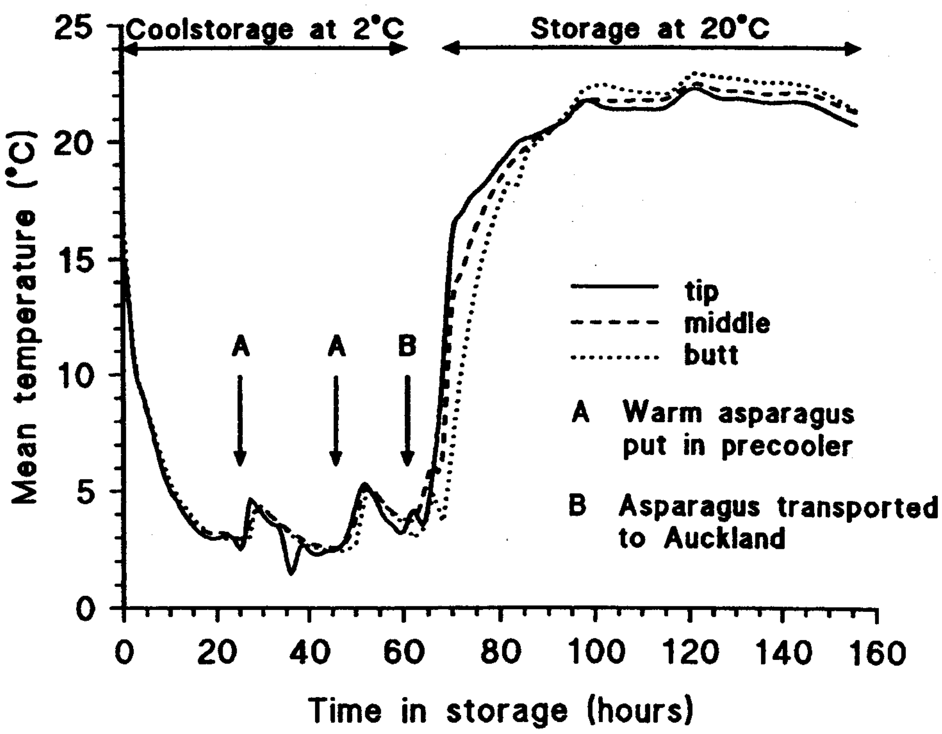

Figure 3. Mean temperatures at the mid region of asparagus spears during hydrocooling with iced water at 0°C, or during air cooling either passively or rapidly using high humidity air (RH 95–98%) at 2°C. Results are for asparagus spears harvested in November (H2).

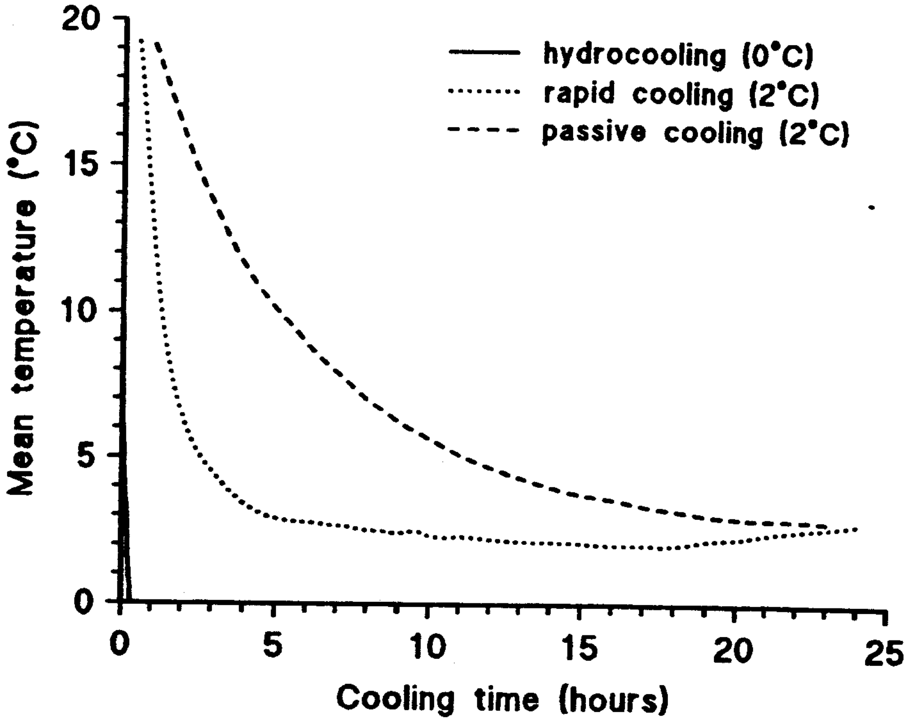

Table 1.1 The effect of hydrocooling (H), and rapid (R) and passive (P) air cooling on the incidence of tip rot (%), and quality (visual rating, weight loss (%), toughness (N) at 6 cm from the tip) of asparagus spears after periods of storage at 2°C and 20°C. (n = 40, 40, 4 and 40 for tip rot, visual rating, weight loss and toughness, respectively).

Cooling Tmt.	Days at 2°C	Days at 20°C	Incidence of tip rot (%)	Visual score	Weight loss (%)	Toughness (N)
H	3	4	3.0	3.7	4.1	61.1
		7	18.0	6.8	10.4	67.8
	21	1	3.0	3.0	3.6	57.6
		4	30.0	7.2	9.1	76.1
R	3	4	8.0	4.1	8.9	64.7
		7	18.0	7.2	14.1	72.0
	21	1	8.0	3.4	7.4	57.2
		4	28.0	7.1	16.2	59.5
P	3	4	13.0	4.2	8.6	65.3
		7	43.0	7.7	13.6	76.0
	21	1	8.0	3.7	7.1	61.4
		4	25.0	7.1	16.1	63.6
Statistical comparisons: LSD ($p<0.05$)						
HvsRvsP	3	4	9.7	0.38	4.2	6.12
		7	26.8	0.31	3.7	7.56
	21	1	11.8	0.59	2.4	3.93
		4	19.9	0.22	3.8	4.34
Hydro	3 + 4 vs 21 + 4		18.9	0.50	2.8	5.30
Rapid	3 + 4 vs 21 + 4		13.5	0.57	5.3	5.24
Passive	3 + 4 vs 21 + 4		13.8	0.47	3.7	5.36

Table 1.2 Toughness (N) of asparagus spears as a function of distance from the tip at time of harvest and after various periods of storage at 2°C and 20°C. Data given is for the second harvest (H2), and n = 10.

			Toughness (N)					
	Days at		Distance from tip (cm)					LSD
Cooling Tmt.	2°C	20°C	4	8	12	16	20	($p < 0.05$)
	At harvest		58.5	66.0	80.6	90.2	142.1	21.54
Rapid	3	4	49.0	66.4	82.6	90.0	152.0	28.08
		7	45.9	69.7	85.1	85.3	127.8	26.58
	21	1	65.1	73.9	87.4	98.0	142.2	21.27
		4	53.2	74.6	93.9	101.1	196.4	46.54
Passive	3	4	44.5	72.0	89.2	93.8	131.1	18.31
		7	58.2	73.9	85.8	93.3	193.7	67.86
	21	1	53.9	65.1	75.8	79.1	145.2	29.09
		4	53.5	86.9	111.5	114.7	218.9	61.43
Hydro	3	4	45.8	60.9	80.5	102.9	175.2	30.30
		7	51.4	63.8	73.5	87.3	161.9	29.31
	21	1	47.6	57.2	73.4	82.4	149.6	24.36
		4	41.2	57.5	78.7	87.3	164.6	35.03
Statistical comparisons: LSD ($p<0.05$)								
Between tmts.	3	4	6.97	11.38	13.83	20.08	51.30	-----
		7	8.35	12.12	15.86	20.41	97.01	-----
	21	1	10.84	11.80	11.25	11.97	51.27	-----
		4	7.80	14.61	21.09	29.19	101.93	-----

Table 1.3 Respiration and ethylene production rates of asparagus spears subjected to either hydrocooling, rapid or passive cooling methods and then stored at 2°C for 3 days or 3 weeks. Rates given are for spears held at 20°C for 5 days after coolstorage, and are means of 4 replicate bunches of 10-15 spears per treatment.

Cooling Treatment	Storage time (days)	Respiration rate (ml CO_2/kg/hr)	Ethylene prod. rate (µl C_2H_4/kg/hr)
Hydrocooling	3	69.62	trace[1]
	21	88.33	trace
Rapid	3	80.74	trace
	21	90.93	trace
Passive	3	83.88	trace
	21	100.00	trace
Statistical comparisons: LSD ($p<0.001$)			
	3	13.2	---
	21	7.8	---

[1] trace = below detection limits.

Similarly, visual quality of spears was significantly less when spears had been held at ambient temperatures prior to hydrocooling for 24 hours, compared to the visual quality of spears at harvest (Table 2.1). Delays of up to 12 hours prior to hydrocooling had no effect on visual quality of spears stored for 3 days. When spears had been stored for 3 weeks however, the visual quality of spears was affected by a 4 hour delay although further delays did not result in a greater effect. However, the visual quality of the spears, irrespective of time of hydrocooling, was marginal or less than that acceptable for sale after 4 days of shelf life.

Spear toughness also differed significantly between those spears which had been hydrocooled at different times after harvest. In general, spear toughness increased with increasing delays after harvest, although this effect was not always consistent. When storage time is considered, only those spears which were hydrocooled 24 hours after harvest were tougher than spears cooled at other times, but spears that had been cooled 4 or 8 hours after harvest and stored for 3 days or 3 weeks, respectively, were also tougher than corresponding spears hydrocooled at other times after harvest. Weight loss was not affected by a delay prior to hydrocooling.

4.3. Effect of time of season.

Overall when both short and long storage times are considered as well as the method of cooling, the incidence of tip rot in spears harvested during the early or late stage of the season was not significantly different. However, the incidence of tip rot in spears that had been passively cooled after being harvested during the late stage of the season and then stored for 3 weeks, was higher than corresponding spears harvested during the early stage of the season (Table 3.1). Other differences in tip rot did occur between spears harvested at early and late stages of the season but these were not consistent between short and long term storage or between the methods by which the spears were cooled.

Only weight loss during storage was consistently different between spears that had been harvested at early and late stages of the season (Table 3.1). Spears which had been harvested during the late stage of the season lost significantly less weight during storage and shelf life than spears harvested during the early stage of the season.

No differences in spear toughness were detected other than for spears that had been hydrocooled. Spears that had been harvested during the early stage of the season, and then stored for 3 weeks, were significantly tougher than corresponding spears harvested later in the season. However, overall, spear toughness and visual quality were not consistently different between spears harvested at early and late stages of the season.

Table 2.1 The effect of delays between harvest and hydrocooling on the incidence of tip rot, and the quality of asparagus spears (visual rating, weight loss (%), toughness (N) at 6 cm from the tip) after storage at 2°C for 3 or 21 days, and 4 days at 20°C. Data given is for the second harvest (H2), and n = 50, 50, 4 and 50 for tip rot, visual rating, weight loss and toughness, respectively.

Days at 2°C	Quality Parameter	Delay at ambient (hrs)						LSD
		0	2	4	8	12	24	$p<0.05$
3	Tip rot	2.0	8.0	2.0	10.0	14.0	24.0	12.9
	Visual	2.1	2.2	2.3	2.6	2.3	5.3	0.9
	Wt. loss	nd[1]	nd	nd	nd	nd	nd	----
	Toughness	48.7	51.8	63.4	53.4	51.9	59.6	7.8
21	Tip rot	18.0	20.0	32.0	20.0	28.0	64.0	21.2
	Visual	6.3	6.7	7.0	7.0	7.0	7.0	0.3
	Wt. loss	7.7	7.4	6.7	8.1	7.8	7.9	2.0
	Toughness	46.2	49.5	55.0	59.8	43.9	59.1	11.6
Statistical comparisons (comparing 3 and 21 days coolstorage):								
LSD ($p<0.05$)	Tip rot	22.6	14.7	15.2	14.1	20.0	17.0	----
LSD ($p<0.001$)	Visual	0.8	0.7	0.5	0.5	0.5	1.5	----
LSD ($p<0.05$)	Toughness	9.0	2.2	9.3	8.5	9.5	10.5	----

[1]nd = not determined

Table 3.1 The incidence of tip rot, and quality of asparagus spears (visual rating, weight loss (%), toughness (N) at 6cm from the tip) harvested during October (H1) and November (H2), and subjected to rapid cooling, passive cooling or hydrocooling before storage at 2°C for 3 or 21 days, and 7 days at 20°C. (n = 40, 40, 4 and 40 for tip rot, visual rating, weight loss and toughness, respectively).

Harvest	Cooling Tmt.	Days at 2°C	Tip rot (%)	Visual rating	Wt. loss (%)	Toughness (N)
H1	Hydro	3	3	3.7	4.1	61.1
		21	30	7.2	9.1	76.1
	Rapid	3	8	4.1	8.9	64.3
		21	28	7.1	16.2	59.5
	Passive	3	13	4.2	8.6	65.3
		21	25	7.1	16.1	63.6
H2	Hydro	3	15	4.3	0.7	63.7
		21	23	6.8	7.5	53.3
	Rapid	3	5	4.3	5.3	64.5
		21	35	6.7	9.5	60.6
	Passive	3	3	4.1	4.8	57.8
		21	38	6.8	9.6	58.1
Statistical comparisons:	LSD ($p<0.05$)					
	Hydro	3	13.9	0.5	2.6	5.8
		21	22.2	0.3	2.2	4.5
	Rapid	3	7.6	0.6	3.1	5.1
		21	16.1	0.2	3.3	4.8
	Passive	3	10.8	0.5	3.7	6.3
		21	11.2	0.2	3.7	6.0

5. DISCUSSION

Since asparagus spears are susceptible to chilling injury, the symptoms of which include water-soaked tissue (Hardenburg et al. 1986), and rates and time of cooling can influence the degree of chilling injury in chilling-sensitive produce. It is possible that tip rot is a result of postharvest temperature management. However, results of this study do not support this hypothesis, although it was demonstrated that the apical tissues of the spear cool and heat faster than basal tissues of the spear.

Postharvest temperature management does not appear to be an initiating or a major factor influencing the incidence of tip rot in asparagus. The incidence of tip rot in spears after both short and long term storage was not influenced by method of cooling. The methods of cooling compared in the present study are all commonly used in commercial packhouses. Whilst the time to reach storage temperature varied markedly from approximately 6 minutes in the case of hydrocooled spears to more than 12 and 48 hours for rapid and passively air cooled spears, respectively, the incidence of tip rot was the same. However, postharvest temperatures may influence the rate at which tip rot develops once it is initiated in spears, as the incidence was always higher during shelf life than during storage. Similarly, with increasing storage time, the incidence of tip rot increases during storage and after shelf life. This is not dependent on the method of cooling employed and is more likely to reflect the increasing rate of expression of tip rot in spears as they progress towards senescence.

A delay prior to cooling also does not appear to be an initiating factor in tip rot, unless delays are excessive and beyond 12 hours after harvest. There was some indication that tip rot increases with increasing delays since the lowest incidence occurred when spears were immediately cooled after or within 4 hours of harvest, but the differences in the occurrence of tip rot were not significant. These differences may have resulted from the fact that spears that were cooled immediately or up to 4 hours after harvest were handled by different individuals than those cooled later.

Visual quality and toughness of spears was not consistently influenced by the method and rate of cooling. Spears which had been hydrocooled tended to retain a fresher appearance and be more tender than rapidly and passively cooled spears but only during short term storage. Any benefit was not retained when spears were stored for 3 weeks. Similarly, delays up to 12 hours prior to cooling also had minimal or no significant effect on visual quality and spear toughness, although there was a trend for these spear characteristics to decrease and increase, respectively, with increasing delays prior to cooling. Therefore, whilst the results indicate that there is no need for urgency in cooling spears after harvest, it is likely that under some instances, delays prior to cooling will be significantly detrimental to quality. In this study, the ambient temperature was in the range 16-18°C, and where ambient temperatures are higher than this, both spear toughness and visual quality may be adversely affected by delays in cooling. The lack of a significant effect on spear quality by short term delays prior to hydrocooling has also been reported by King et al. (1986).

The inconsistent responses of spears to cooling treatments may reflect the methods employed to assess spear quality, rather than an absence of treatment effects. Visual quality is subjective, despite the use of a scale. Similarly, the shear press may not accurately reflect changes in spear toughness because of cavitation that occurs in many spears. Much of the variability in spear toughness may be a result of cavitation, and therefore, a more suitable method for assessment of toughness may be required.

Although in this study only two harvest dates were investigated, influences of time of harvest on the incidence of tip rot appear to be minimal. Overall, the incidence of tip rot was the same in spears harvested during the early or late stage of the season. Physiologically, the spears from the two harvests appeared not to differ, except with respect to weight loss. It should have been possible to detect overall trends in incidence of tip rot over the season in this study, even if fluctuations occurred on a daily or weekly basis.

In the absence of a consistent effect of postharvest temperature management on the incidence of tip rot, other factors need to be considered. Water soaked tissue is a common feature of bruised tissue in fruit (MacLeod et al. 1976). Preliminary observations made of current postharvest handling practices relating to the washing and processing of spears prior to packing suggests that physical damage can occur very frequently (Appendix 2). Much of this damage may remain undetected at the time of packing, but ultimately appear as tip rot. Furthermore, handling of the spears appears to be the largest variable on a daily and packhouse basis. It is hoped to investigate this possibility in the next season.

6. CONCLUSIONS

The method and rate of cooling does not significantly influence the incidence of tip rot, or the visual quality and toughness of spears, but delays in excess of 12 hours prior to cooling are likely to result in a higher incidence of tip rot and spears of lesser quality than when spears are cooled sooner. Overall spear quality may be marginally higher in spears that are hydrocooled than spears that are rapidly or passively air cooled. Postharvest temperature management is unlikely to be a major factor in the initiation of tip rot but does influence the rate at which the disorder develops. The time of season at which spears are harvested also does not appear to be a factor in the incidence of tip rot. Spears should be rapidly cooled either by hydrocooling or forced humidified air within 4 to 12 hours of harvest.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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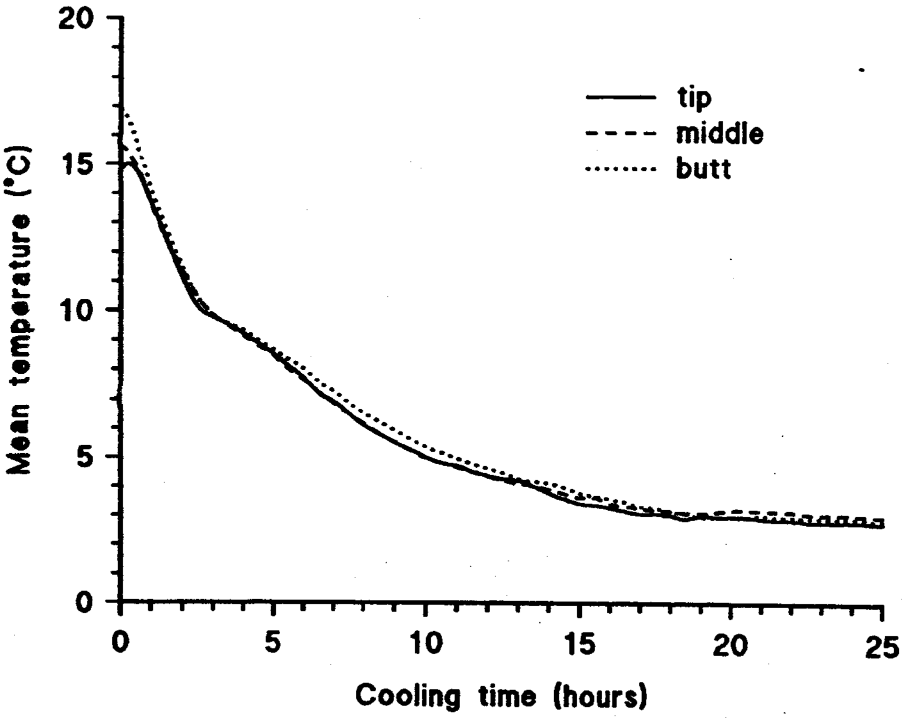
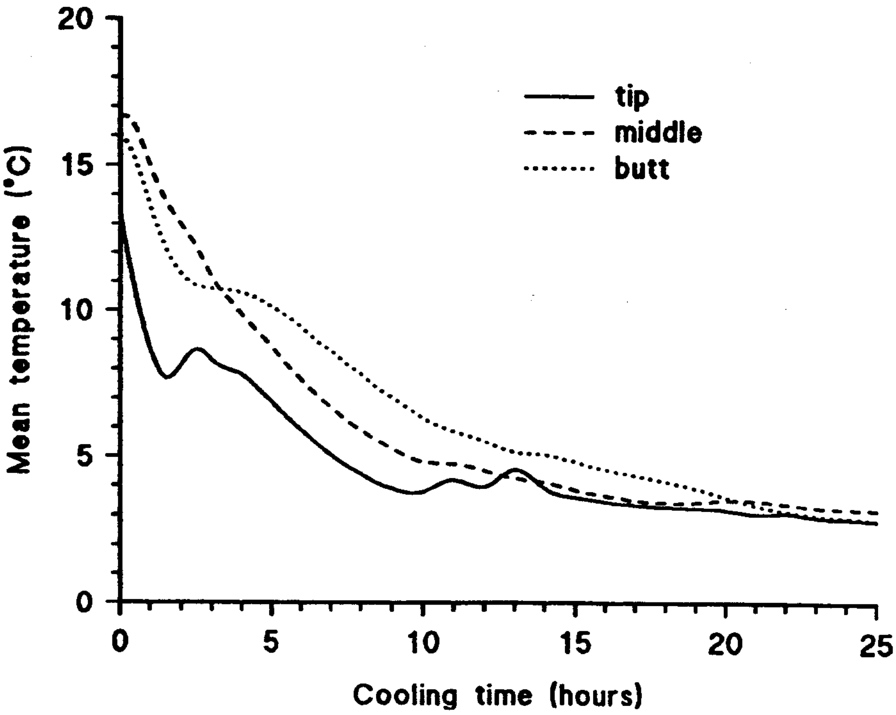
9. APPENDIX 1

Temperatures during hydrocooling, rapid and passive cooling of asparagus spears harvested in October (H1) or November (H2).

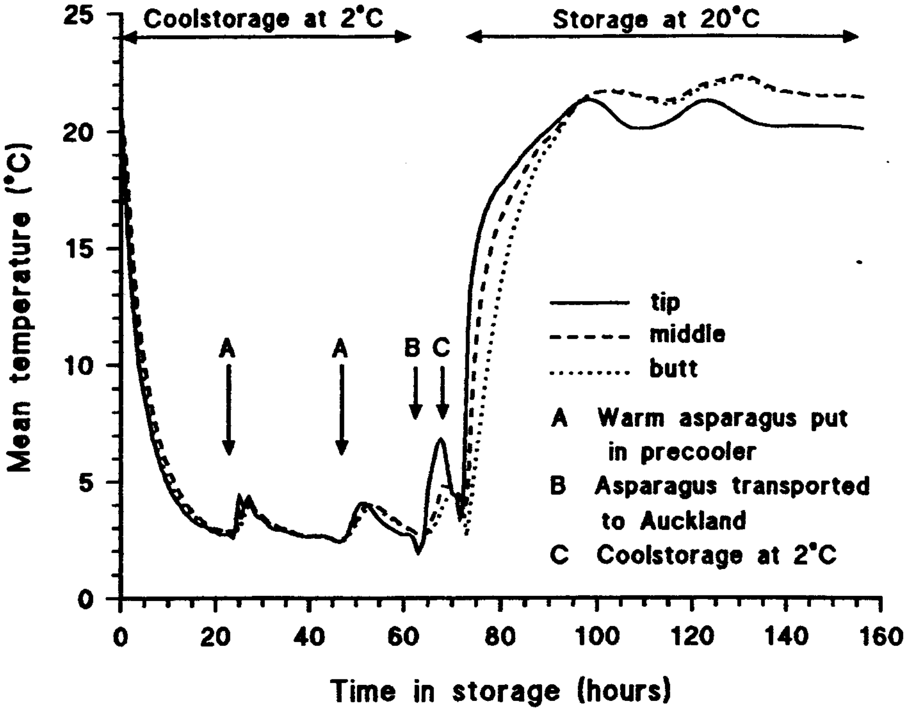
(A) Temperatures during passive cooling (H1).



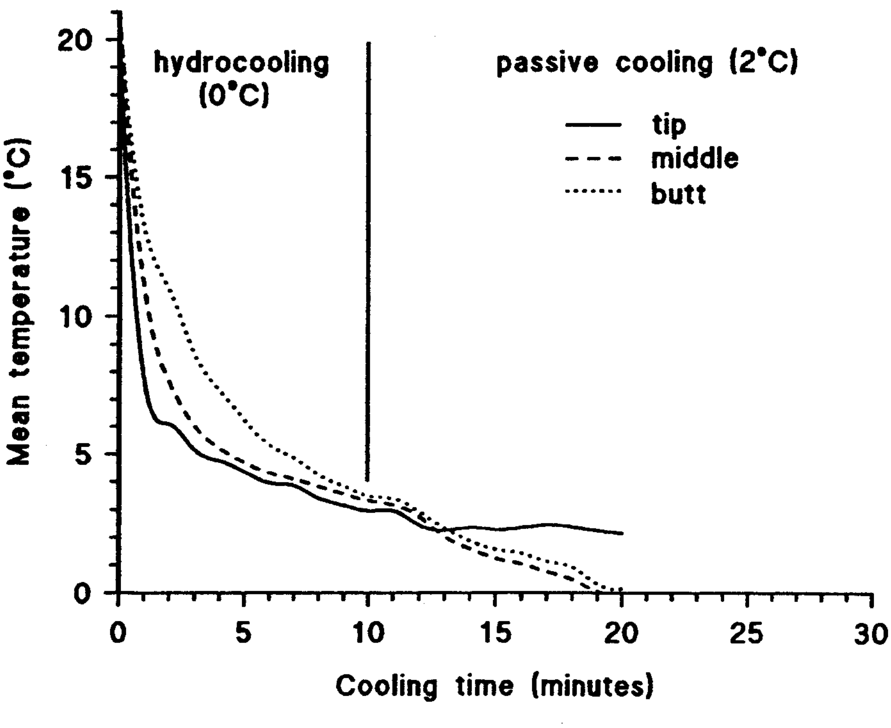
(B) Temperatures during rapid cooling (H1).



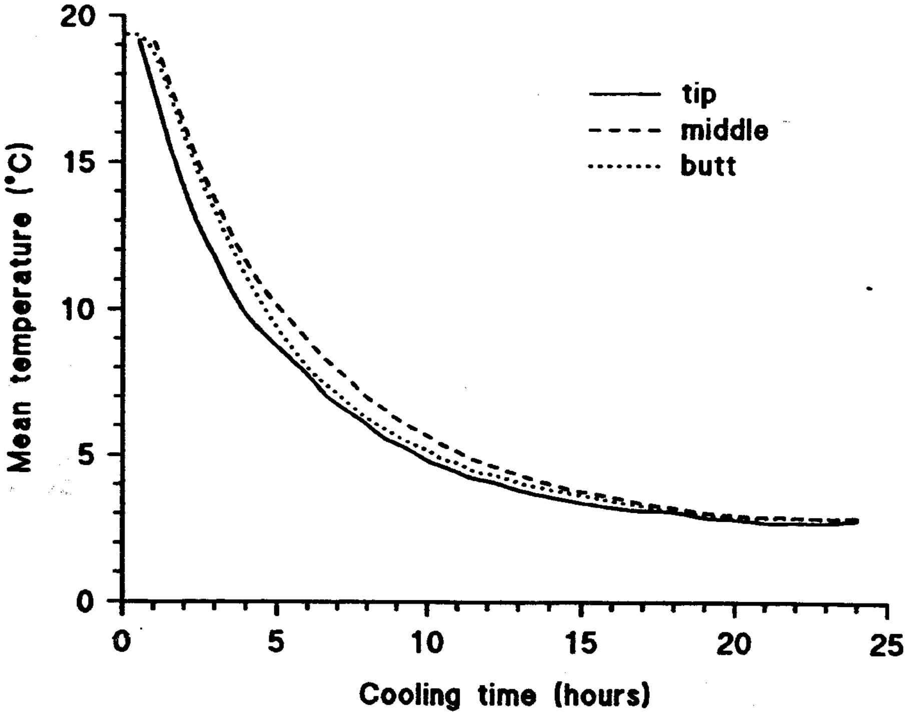
(C) Temperatures during passive cooling, transportation and removal to 20°C (H2).



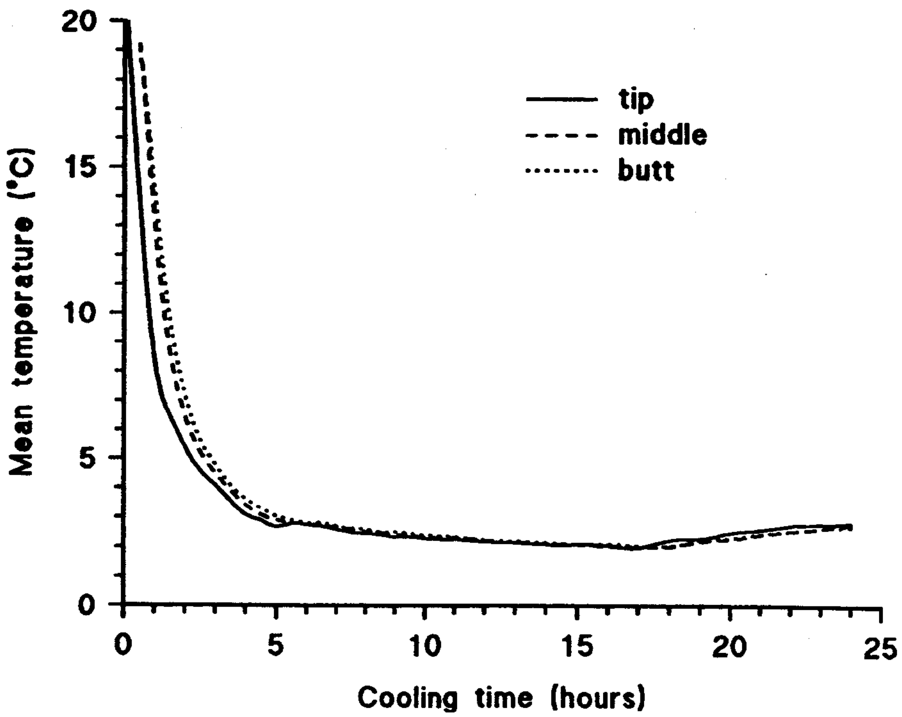
(D) Temperatures during hydrocooling (0°C) and storage at 2°C (H2).



(E) Temperatures during passive cooling (H2).



(F) Temperatures during rapid cooling (H2).



10. APPENDIX 2

Observations on the Postharvest Handling of Asparagus.

Visits were made to three packhouses to observe the postharvest handling of asparagus. Particular attention was made of those procedures that may predispose the tip of the asparagus spear to physical damage during washing, cutting, grading and packing of spears. Methods used to cool spears were also noted. However, as only preliminary observations were made, technical specifications and details are not included in the observations outlined below.

1. NGAHINAPOURI (Peter Van DEURSEN)

Spears, predominantly packed into plastic field bins, were washed under a jet of high pressure water from a hand-held hose. The containers were shaken by hand to ensure that most spears were washed directly. In general, the amount of shaking was related to the degree of soil contamination on the spears. Containers with heavily soiled spears were vigorously shaken and repeatedly washed. Washing and handling of field bins was considered to be a potential source of physical damage to the tips of the spears.

Once washed, bunches (10-15 spears) were manually placed onto a moving conveyor belt and aligned for cutting. Alignment was achieved by using a steel plate, which had been vertically placed over the conveyor, as a reference point. The tips of the spears were "thrust" against or towards this plate, and then spread on to the moving conveyor so that 1 to 3 spears lay on the conveyor at any one location. Since the plate was fixed, some tips were observed to scrape against the plate, and therefore, the plate is a potential source of physical damage. Damage could occur when spears are initially aligned against the plate as well as after alignment when spears are moving along the conveyor. The position of the plate was movable so as to alter the final length of the spears, but during operation, it remains fixed and unprotected.

A sponge rubber press wheel maintained spears in position whilst they were cut by a revolving blade. After being cut, spears were washed with chlorinated water as they moved beneath two spray jets.

Processed spears were sorted into export, local and processing grades and packed into wooded boxes. Obviously, damaged spears were discounted for export. The packed boxes were stacked onto pallets and the pallets were then strapped. During strapping, the lids of those boxes located at the top of the stack were forced down onto the tips of the spears, and therefore, strapping could also be a potential source of physical damage.

Completed pallets were precooled by use of a high humidity precooler. Usually spears were placed onto the cooler within 6 to 8 hours of harvest.

The efficiency and productivity in this packhouse was considered to be higher than average. Four lines were operated, each with 4-6 people per line.

The packhouse had experienced problems with tip rot, but no details as to the extent and frequency were available.

2. HORSHAM DOWNS (Roger and Leslie WHYTE)

Overall, the handling of spears in this packhouse was considered to be gentler than in the other two packhouses, because spears were moved less often and/or less vigorously. Relative to the other two packhouses, this was a smaller operation with only 5 to 7 people employed.

A large water tank fitted with a moving conveyor system was used to wash spears prior to grading and packing. Crates, which were often made of wood, containing harvested spears, were lowered into the tank of chlorinated water. Occasionally, the crates of spears were washed with tap water using a hand-held hose, prior to the transfer of the spears to the washing tank. The crates were completely submerged in the tank for up to 10 minutes, before emerging from the tank. Spears were washed with a water spray after emerging from the tank. The tank water was recirculated after passing through a filter. Although spears were not necessarily manually handled, forcibly maintaining spears under water for long periods of time could lead to some physical damage.

passage of each carton through the hydrocooler was 15 to 20 minutes. After hydrocooling

After washing, spears were manually placed onto a moving conveyor belt and aligned for cutting. Four people loaded the spears onto the conveyor. A strip of sponge rubber, that had been fixed to the entire length of the conveyor belt, was used as a reference point. Spear tips were placed against the side of the rubber strip, which was approximately 2.5 by 2.5 cm in cross section. Occasionally, tips of the spears remained on the top of the rubber strip than against the side. When the bases of these spears were being cut, a sponge rubber press wheel forced the tips down against the side of the rubber strip, and therefore, incorrect placement of spears could lead to physical damage at the tip.

Once export grade spears were removed (2-3 people grading and packing) from the moving conveyor, a second revolving blade recut the spears to local or process grade standards (1 person grading and packing).

Graded spears were packed into wooden boxes, which once packed were hydrocooled by placing the bases of the boxes into iced water for 10 minutes. Only the bottom of the boxes were in the iced water, with 5-10cm of the spears being submerged, but at all times the tips remained above the water. Boxes were than transferred to a conventional coolstore, and held there until transport to export markets.

Tip rot had been noted in export consignments, but no details as to the levels present were known. The hydrocooling method used was a direct response to minimise the incidence of tip rot present, but the continued presence of tip rot suggested that hydrocooling was not a major influencing factor.

3. ARAPUNI (Trevor SYNGE - packhouse manager)

This packhouse was notable for the use of an automated electronic sorting and grading system. The system was considered to be a prototype and therefore was still being evaluated. Some modifications were anticipated in the future.

Spears were collected from the field in wooden crates. Harvested spears were washed with tap water, but only if the spears were considered to be heavily contaminated with soil, which was usually when spears were harvested after heavy rainfall. On all other occasions, spears were not washed prior to placement onto the grading system.

Two packing lines were operating in this packhouse. For cutting to length, the tips of the spears were manually aligned with one edge of the moving conveyor belt. Up to 3 persons were involved in ensuring spears were correctly aligned. Press wheels then kept spears in position as they were washed with a spray of chlorinated water and cut by a revolving blade. The trimmed spears then travelled up onto a second conveyor, but in each case spears maintained their relative aligned position.

Light sensors, which were positioned above the second conveyor belt, determined the width and butt colour of the trimmed spears. Those spears that had purple or white butts rather than green butts were graded as not suitable for export and remained on the conveyor belt to be recut to a shorter length by a second revolving blade. Export grade spears were sorted into thin and thick spears and ejected from the conveyor belt first. Local grade spears were also graded into thick and thin spears.

Each spear was physically removed from the conveyor by impact from a piston rod, which was actuated by air pressure. The rods made contact with the cut base of the spear such that the spear, tip first, was fired into a cylindrical shute. The spears slid down the sloping shute at speed. At the bottom of the shute, the spear tip made contact with a sponge rubber mat, which had been fixed against a solid plate. The plate was located vertically above a moving conveyor, and served as a partition between graded spears as well as stopping spears once they had emerged from the shute.

Many of the tips were damaged when the spear was fired into the shute or when the spear made contact with the rubber mat at the bottom of the shute. Damage was usually visible since apical bracts were usually dislodged. It was hoped to reverse the orientation of the spears down the shute so that the bases of the spears are first into and out of the shute.

All graded spears were forced down their respective shutes and eventually ended up on a common conveyor belt but as one of 4 separated files of spears. The conveyor rotated in a direction that was 90° to the direction of the shute. Spears were packed into wooded boxes, which were than placed into a commercial hydrocooler. The average time for the passage of each carton through the hydrocooler was 15 to 20 minutes. After hydrocooling was completed, the boxes were stacked onto pallets and transferred into conventional coolstores.

It was claimed that the packhouse had not had a problem with tip rot, and had experienced only a very low incidence of tip rot in export consignments.