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Postharvest handling of fresh carrots for Asia

A report prepared for
Fresh Vegetable Industry Development Committee
Vegfed
Box 10 232
Wellington

D W Brash, L H Cheah, A P Marshall, R C Butler & B L Bycroft

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New Zealand Institute for Crop & Food Research Limited
Private Bag 4005, Levin, New Zealand

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1 EXECUTIVE SUMMARY

This report covers the first year of research into improving the out-turn of fresh carrots exported to Asian markets. Our research focused on measuring the storage potential of carrots stored at 0-1°C, on assessing the benefits of rapid cooling and good sanitation practices and on identifying important postharvest diseases.

We stored, washed and hydro-cooled carrots from three harvests, for up to 12 weeks using export carrots from Ohakune. We measured the effect of chlorination and delays of up to one week at 15°C on carrot quality after four weeks in storage. We identified micro-organisms linked to root and crown rots found in stored carrots.

Carrots stored well for four weeks at 0-1°C. We recommend minimising delays in cooling prior to storage. We did not obtain a response to chlorination, probably because of the clean wash and rinse water used. We identified a number of diseases in the carrots, the most pathogenic being *Sclerotinia sclerotiorum* (watery soft rot) and *Thielaviopsis basicola* (black mould rot).

The report makes a number of recommendations for improving the quality of export carrots and on the direction of future research.

2 RECOMMENDATIONS

1. Cool carrots to below 5°C within 24 hours of harvest.

2. Store carrots at 0-1°C.

3. Maintain high humidity in storage. Condensation inside plastic liners is undesirable and is minimised by maintaining constant storage temperature and draining carrots prior to packing.

4. Researchers and growers should work together to identify field, harvest and packing managements to improve export out-turn. Likely areas for research work include:

   - a review of the crop rotation/soil-borne disease pattern. It is likely that the incidence of most postharvest diseases is related to the level of infection in the field. Spray programmes may need to be upgraded.

   - choice of cultivar. It is likely that some cultivars store better than others, particularly if selection for disease tolerance has been carried out during cultivar development (cultivar choice also depends on yield, shape, colour and carotene content).

   - a review of harvesting practices to minimise handling damage e.g. it is likely that the incidence of bacterial soft rot (*Erwinia* sp.) is related to crown damage caused by severe trimming.

   - a review of packhouse/coolstore management washing and grading to avoid injuries which allow disease entry. In the UK, some carrot growers and packers are moving from barrel to brush washers for gentler handling and reduced root damage (Flaherty, 1995). Some fungicides (Benlate and Rovral) have been recommended as a postharvest dip overseas (e.g. ADAS 1984) but their use in New Zealand requires testing and approval by the Pesticide Board.

3 INTRODUCTION

Exports of fresh carrots have grown rapidly in recent years from $0.45 million in 1990-91 to $4.35 million in 1994-95. The demand is primarily from Japan, but other markets in Asia are also being developed. Growers and exporters have taken high quality carrots grown for the domestic market and modified their handling systems to meet export requirements. Purpose-built packhouses and coolstores close to the main growing areas are only just being built.

This project is the first year of investigation into the postharvest handling practices for export carrots. The main emphasis has been on trying to identify the likely causes of poor market out-turns of carton-packed carrots sent to Asian markets. The research work has concentrated on disease identification and cool chain management. These two areas of concern were identified in discussions with growers (mainly at Ohakune) and exporters (from Auckland and Christchurch).

Growers supplying the local market in New Zealand have developed a system of washing carrots, packing them in large perforated plastic bags (10-20 kg) and transporting the carrots at ambient temperatures. Carrots reach retail markets within 3-4 days of harvest. Export carrots, in contrast, must be packed in plastic bag lined cartons and stored for about four weeks prior to sale. Growers and exporters have found that carrots are difficult to cool once in the carton. Many believe that problems of poor out-turn are related to packing cartons of carrots (at ambient temperatures) into refrigerated sea containers. The diseases and sprouting that have been noted in poor out-turns are thought to be related to inadequate temperature control during storage and particularly, inadequate cooling prior to storage.

The postharvest requirements of carrots are well-documented. Story & Simons (1989) recommend storage at 0°C and 95-100% relative humidity, and rapid cooling. Their manual recommends carrots should be cooled to below 5°C within 24 hours of harvest.

Hydrocooling to 0-1°C after washing is recommended by A. Kader (1992). Cooled carrots are then quickly graded, packed and held in a coolstore prior to transportation by refrigerated truck and sea containers to the export markets.

4 METHODS

We carried out two experiments, one to assess the storage potential of New Zealand carrots and another to examine the effects of poor postharvest handling. We also identified the diseases that developed in carrots during storage.

4.1 Storage potential experiment

The objective of this experiment was to show that, with appropriate postharvest management, carrots have a long storage life and should be able to be stored for longer than the four weeks required for seafreight to Asian markets.

We obtained 100 kg of freshly harvested and washed carrots from Ohakune on three occasions (23 June, 18 July and 15 August, 1995). The carrots from each harvest were held overnight at 10-15°C and at high humidity and then hydro cooled to 1°C, washed in 50 ppm chlorine for 5 minutes and rinsed at 1°C, allowed to drain and packed into eight 10 kg boxes with plastic liners.

The boxes were put into storage at 0-1°C and assessed immediately, and after four, eight and 12 weeks (Table 1). Two boxes of carrots were assessed on each occasion.

The assessments were for disease and visual appearance. Samples were sent for disease identification as required.

4.2 Sanitation and delayed cooling experiment

The objective of this experiment was to show that good sanitation and rapid cooling of carrots after harvest maximises storage potential.

We obtained 100 kg of freshly harvested and washed carrots from Ohakune on three occasions (23 June, 18 July and 15 August, 1995). The carrots from each harvest were held overnight at 10-15°C and at high humidity.

Nine treatments were set up at each harvest (Table 2) an initial sample and eight storage treatments, all stored for four weeks in 10 kg boxes with plastic liners. The storage treatments were combinations of two sanitation treatments (either a five minute water rinse at 15°C then drain and pack, or 50 ppm chlorine for five minutes followed by a five minute water rinse then drain and pack), and four delay periods at 15°C (0, 2, 4 and 7 days), all followed by storage at 0°C.

Carrots in lined boxes were placed in an open stack in a forced air cooler at the end of the appropriate delay period. Temperature logging showed that the carrots took 24 hours to cool from 15°C to 2-3°C in the forced air cooler.

Assessments were made for disease and visual appearance. Samples were sent for disease identification as required.

Table 1: Treatments for storage potential experiment

Treatment	Storage period (weeks)	Temperature (°C)
1	0	0
2	4	0
3	8	0
4	12	0

Each treatment was replicated twice at each harvest, for each of three carrot harvests, i.e. 4 x 2 x 3 = 24 plots.

Table 2: Treatments for sanitation and delayed cooling experiment

Treatment	Sanitation	Cooling procedure
1	No chlorine	Initial sample
2	No chlorine	Direct to storage at 0°C
3	50 ppm chlorine	Direct to storage at 0°C
4	No chlorine	2 days at 15°C then 0°C
5	50 ppm chlorine	2 days at 15°C, then 0°C
6	No chlorine	4 days at 15°C, then 0°C
7	50 ppm chlorine	4 days at 15°C, then 0°C
8	No chlorine	7 days at 15°C, then 0°C
9	50 ppm chlorine	7 days at 15°C, then 0°C

Each treatment was replicated for each of three carrot harvests i.e. 9 x 3 = 27 plots.

4.3 Carrot supplies

Carrots for the storage experiments were obtained from Mountain Carrots Ltd (June harvest) and Kim Young Ltd (July and August harvest).

4.4 Disease diagnosis

Diseased carrots were collected at intervals from the storage experiments and symptoms were recorded. Sections of infected tissues were cut, surface sterilised, then plated onto Potato Dextrose Agar (PDA). Fungal and bacterial isolation and identification were made using appropriate media incubated at room temperature (about 15°C). Pathogenicity tests were also carried out using washed and wounded carrots, inoculated with spores or mycelium of the fungus.

5 RESULTS AND DISCUSSION

5.1 Storage potential experiment

Results are summarised in Figure 1. Development of storage rots was the main cause of loss of quality. The 'no rots' category always consisted of over 95% of carrots of quality acceptable for export (with a small percentage downgraded because of splitting, insect damage and embedded stones). Each carrot was rated once for the most obvious defect; carrots with obvious crown rot did not have root rot, but carrots with obvious root rot often had some crown rot as well.

Crown rot symptoms developed after four weeks in storage, initially, mainly as sparse white mycelial growth in the residue of the tops and sometimes as blackening of root tissue at the base of the crown.

We isolated *Rhizopus stolonifer, Fusarium sambucium, Cladasporium* sp. and *Penicillium* sp. from carrots showing these symptoms.

Some crowns (16% by weight) showed soft and slimy cream rots (identified as the bacterial soft rot *Erwinia carotovora).*

Root rots predominated after eight and 12 weeks storage. The main root rot observed was a grey spot or lesion 2-3 mm in diameter. No fungal pathogen could be isolated, which suggests that this type of root rot was a result of a physiological breakdown. A low proportion of root rots (estimated at up to 5% by weight) were caused by *Thielaviopsis basicola* (a black mould rot) and *Sclerotinia sclerotiorum* (a watery soft rot of carrot flesh with white cotton nests of hyphae on the outside).

Each harvest was treated as a replicate for statistical analysis, meaning that differences between harvests cannot be analysed statistically. It was noticeable, however, that the response to storage varied between harvests. Crown rot incidence was much higher after four weeks storage for the first harvest. Root rot incidence after eight and 12 weeks storage was much higher on the final harvest. Differences between harvests would be expected and could be related to factors such as differences in soils, paddock history, carrot size, stage of season and postharvest handling systems.

The development of root rots or lesions after four weeks storage indicates that more work is required to develop cultivars, field management techniques and/or postharvest management practices to allow carrots to be stored for longer than one month.

Development of crown rot symptoms early in storage may be more of a cosmetic problem. For exporters, management techniques to reduce crown rots are highly desirable.

Carrots showed "white blush" on the roots when they were allowed to dry on removal from storage. This symptom is thought to be caused by abrasion damage. The surface of the carrot is physically damaged during harvest and postharvest handling. We do not know how much of this symptom can be eliminated by careful handling.

5.2 Sanitation and delayed cooling experiment

We did not obtain a significant benefit from the use of chlorine. Washing at the packhouse and the rinsing prior to storage in clean water must have been sufficient to maintain adequate sanitation. Higher chlorine levels may be beneficial and should be tested in future work. Careful monitoring of water quality and use of chlorine is likely to be important if water is to be recycled.

The effects of delays in cooling are summarised in Figure 2. The proportion of carrots in the 'no rots' category decreased in storage and with increasing delays prior to cooling. Root rots increased significantly as cooling was delayed. Delayed cooling also allowed tops to sprout (about 20 mm growth for seven days delay). Crown rot increased during storage.

The comments on the importance of preventing root rot development (Section 5.1) are also relevant for this experiment.

5.3 Postharvest diseases

Results of disease symptoms, micro-organisms and their pathogenicities for cool-stored carrots are summarised in Table 3. Photographs of the diseases are also included (Figure 3).

S. sclerotiorum and *T. basicola* are the most pathogenic of the micro-organisms isolated from carrot rots. Although their incidence at the end of storage was low, these diseases are likely to spread rapidly at warmer temperatures during storage and/or shelf-life. *T. basicola* was a first record for New Zealand.

Alternaria radicina (black rot) was detected at very low levels. This disease causes large storage losses in the US).

Table 3. Disease symptoms, micro-organisms and their pathogenicities on cool stored carrots.

Symptoms	Micro-organisms	Pathogenicity rating*	Symptoms in laboratory culture
1. White soft rot	*Sclerotinia sclerotiorum*	5	Soft, watery rot with white, cotton-like fungus. Black sclerotia were formed on the rotted tissue after culture.
2. Top rot (no mycelium)	*Erwinia carotovora*	3	Slimy soft rot in crowns. Bacteria also caused cheese-coloured rot on wounded tissue.
3. Black top rot (with mycelium)	*Rhizopus stolonifer*	3	Firm black rot on carrot crown with mycelium. Remains of the leaves were a probable cause of this rot.
	Fusarium sambucium	3	
	Cladasporium sp.	1	
	Penicillium sp.	0	
4. Slimy soft rot	*Erwinia carotovora*	3	As in 2.
5. Basal rot	*Pythium* sp.	2	Soft, colourless rot extending 2-3 mm into root tissue.
6. Black mould rot	*Thielaviopsis basicola*	4	Initial symptom was a fine mould growth which later became black. Lesions were 1-2 cm across, irregular in shape and frequently associated with senescent leaves or plant debris.
7. Grey spots (2-3 mm)	Sterile fungus	0	Only observed on carrots stored for 2-3 months. Fine, greyish mycelium growing on roots, later enlarging to 5 mm diameter. Fungus did not sporulate in culture or cause rots in the pathogenicity test.

* Rating: 0 = no rot 1 = slight rot 5 = complete rot

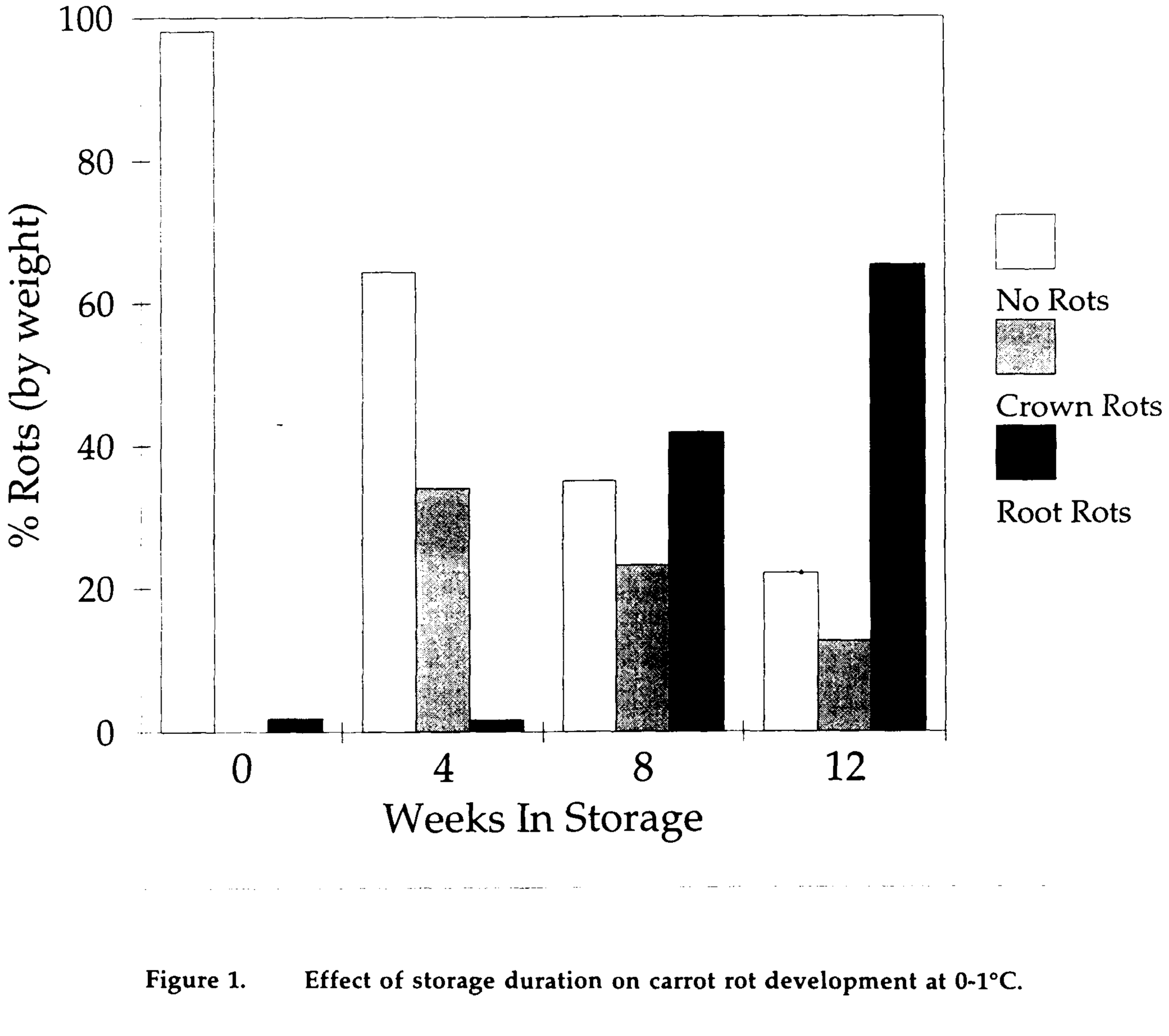

Figure 1. Effect of storage duration on carrot rot development at 0-1°C.

Least significant differences ($p < 0.05$) between storage durations were 23.4 for No rots, 10.7 for Crown rots and 26.1 for Root rots categories. Note that carrots were allocated to one category only so that later in storage many carrots with root rots also had crown rot symptoms.

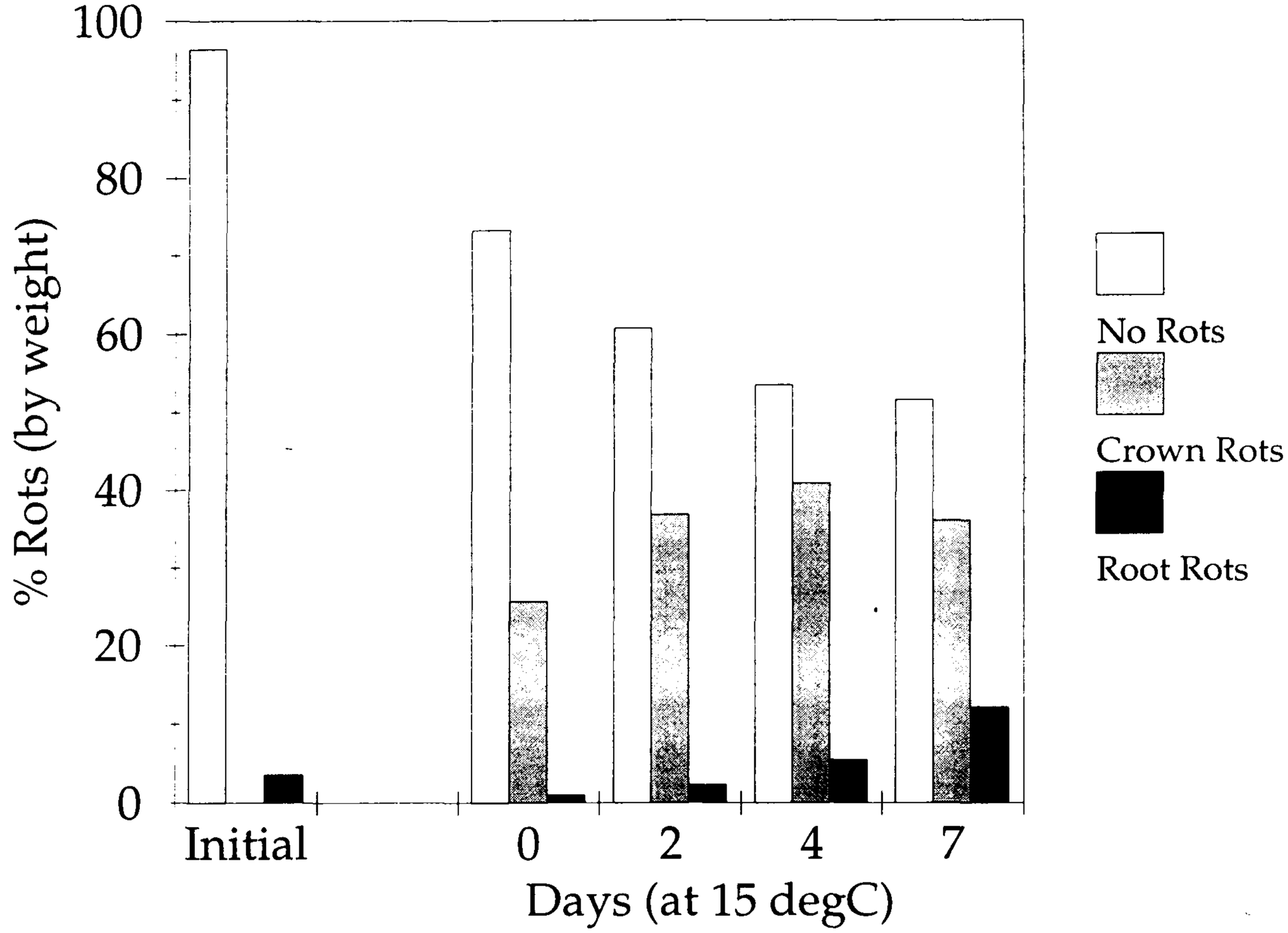

Figure 2: Effect of delayed cooling on carrot storage rots

Least significant differences ($p < 0.05$) for delayed cooling

	Between days	**Initial vs stored**
No rots	12.2	15.0
Crown rots	n.s.	13.9
Root rots	4.6	n.s.

A. Crown rot, firm with white mycelia

B. Crown soft rot including *Erwinia*.

C. Root rot (*Thielaviopsis basicola*)

D. Root rot (sterile grey lesions)

Figure 3. Disease symptoms on stored carrots

6 CONCLUSIONS

1. Carrots stored well for at least four weeks.

2. Delays in cooling resulted in an increased incidence of root rots.

3. A number of bacterial and fungal diseases were isolated from crowns and roots. The most pathogenic micro-organisms were *S.sclerotiorum* and *T. basicola*. These fungi spread rapidly during shelf life. There was a high incidence of micro-organisms of low pathogenicity which suggests that careful attention to field management, harvesting and postharvest management should help increase storage potential. The incidence of *T. basicola* was closely related to the presence of decayed leaf tissue and plant debris on the surface of infected root tissue.

7 REFERENCES

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