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Susceptibility of 'Lisbon' and 'Eureka' lemons to chilling injury

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Summary. 'Eureka' and 'Lisbon' lemons (*Citrus limon* L.) from the Burnett region in Queensland were stored for 14, 28 or 42 days at 1°C followed by 7 days at 20°C to compare their relative susceptibility to chilling injury. The potential effect of cultivar on injury development was examined by harvesting fruit from trees subjected to the same growing conditions to minimise all other variability. Injury appeared in both cultivars after storage at 1°C for 14 days and 7 days at 20°C. The incidence of commercially unacceptable chilling injury (moderate and severe) was significantly higher in Lisbon than Eureka fruit after all storage treatments, except for 42 days at 1°C plus 7 days at 20°C. Eureka and Lisbon lemons had similar respiration rates at 20°C, but respiration of Lisbon following storage at 1°C for 14, 28 and 42 days was significantly higher than that of Eureka. Storage at 1°C for 14 days resulted in elevated respiration in both cultivars, with a peak occurring during the first 24 h. After 28 days at 1°C, peak respiration increased to 51 mg/kg.h for Lisbon and 34 mg/kg.h for Eureka lemons. Respiration increased significantly with longer storage periods, consistent with extensive chilling injury. It is suggested that the lack of commercial success of cold-treated Queensland-grown Eureka lemons is not because they are more sensitive to chilling injury than Lisbon lemons.

Introduction

Chilling injury of commercially cold-disinfested Queensland lemons [*Citrus limon* (L.) Burm. 'Eureka'] has become a significant impediment to the establishment of export markets in Japan (McLauchlan *et al*. 1996). In 1987, a disinfestation schedule against Queensland fruit fly (*Dacus tryoni* Froggat) and Mediterranean fruit fly (*Ceratitis capitata* Weidemann) of 1°C for 14 days was accepted by Japan for exports of Australian lemons (Hill *et al*. 1988). While sea-freight exports of predominantly 'Lisbon' lemons from South Australia and Victoria have proved to be highly successful, the occurrence of chilling injury has restricted similar exports of Eureka lemons from the Burnett area, Queensland's major citrus production region. To date there has been no successful export of cold-disinfested Eureka from the Burnett region.

Cultivar type is known to have a potentially significant effect on susceptibility to chilling injury in citrus (Chalutz *et al*. 1985; McDonald *et al*. 1991). While Lisbon and Eureka lemons are grown in most production regions, the proportion of each cultivar differs significantly. In colder inland regions such as the lower Murray and Victoria, production is based on Lisbon lemons (Forsyth 1988), whereas in Queensland, production is made up of 80–90% Eureka lemons (J. Owen-Turner pers. comm.). There is no information in the literature on the comparative susceptibility to chilling injury of Eureka and Lisbon lemons. Cultivar type may explain differences in damage levels caused by cold-disinfestation in Australian lemons from different production regions.

This paper presents the findings of a study to determine whether Eureka lemons are more susceptible to chilling injury than Lisbon lemons, and whether the lack of commercial success of cold-disinfested Queensland lemons can be attributed to cultivar type. To assess the factor of cultivar, fruit were harvested from trees in the same orchard and subjected to uniform

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production practices, as a strategy to minimise other sources of variability.

Materials and methods

Fruit

Mature Eureka and Lisbon lemon fruit were harvested from adjacent blocks in a single commercial orchard near Gayndah, Queensland (lat. 25°S, 300 km from Brisbane), in April 1996 (early season). Trees of both cultivars were of a similar age and subjected to the same growing conditions, and were chosen with the aim to minimise variability. Fruit were selectively harvested to ensure uniformity of size and colour, and to minimise possible damage caused by oleocellosis. Fruit were not de-greened with ethylene or subjected to any standard commercial wash, fungicide, wax or grading. Cartons were transported by road to the Hamilton laboratory, Brisbane within 6 h.

Treatment

A total of 24 cartons each containing 65 Lisbon or Eureka lemons were stored at 1°C for either 14, 28 or 42 days or continuously at 20°C (3 carton replicates x 4 treatments x 2 cultivars). Fruit stored at 1°C were subsequently transferred to 20°C for a further week of storage to allow chilling injury to develop.

Assessments

Chilling injury was rated visually using a scale of: 0, nil; 1, 1–10% of the rind with injury (mild); 2, 11–50% of the rind with injury (moderate); and 3, more than 50% of the rind with injury (severe). Fruit with a chilling injury rating of moderate or severe are considered commercially unacceptable. The incidence and severity of chilling injury were assessed following each of the storage periods.

The respiration of 10 fruit of each cultivar was monitored under a continuous flow of humidified air at 20°C for 1 week following storage at 1°C or storage at 20°C, or directly after harvest. Laboratory compressed air was passed through suitable gas regulators to provide an airflow of 25 ± 5 mL/min. After passing over $KMnO_4$/purafil to remove any ethylene, this airline was humidified to a dew point of 19°C (equivalent to 93–95% relative humidity), measured by a General Eastern hygro-M2 dew point meter. Fruit were placed in gas-tight containers that were continuously flushed with humidified ethylene-free air. Effluent gas streams were connected to a 50 channel rotary gas sampling valve connected to an infrared gas analyser (IRGA; Horiba PIR-2000) for carbon dioxide analysis.

Statistical analysis

Chilling injury incidence data were analysed as percentage of fruit showing severe injury, percentage showing moderate or severe injury and percentage showing any degree of injury (mild, moderate and severe). The data were angular transformed before being subjected to analysis of variance using the GENSTAT 5.3 statistical package (Payne *et al*. 1993). Respirational data were subjected to 1-way analysis of variance for non-stored fruit (2 cultivars x 20 fruit) at each measurement time. Data for stored fruit were subjected to 2-way analysis of variance (2 cultivars x 2 temperatures x 10 fruit) at each time. Analyses were performed using the DPI-BALF (Biometry, Department of Primary Industries, Queensland) program. Averages of the standard error of the means were calculated from cultivar variances (data for non-stored fruit) and cultivar x temperature variances (stored fruit).

Table 1. Effect of cultivar, storage time and storage stage on the percentage of lemon fruit affected by chilling injury and its severity

Percentages were angular transformed before analysis; back-transformed means are presented, with transformed means (degrees) in parentheses

Storage period	Cultivar	Injury level (% of fruit affected)					
		Severe		Moderate + severe		Any visible injury	
14 days, after 1°C	Eureka	0	(0)	0	(0)	0	(0)
	Lisbon	0	(0)	0	(0)	0	(0)
+7 days 20°C	Eureka	0.2	(2.5)	7.0	(15.3)	58.9	(50.1)
	Lisbon	6.6	(14.9)	24.0	(29.3)	75.2	(60.1)
28 days, after 1°C	Eureka	15.6	(23.3)	44.4	(41.8)	93.1	(74.8)
	Lisbon	25.4	(30.2)	59.1	(50.3)	98.4	(82.7)
+7 days 20°C	Eureka	21.3	(27.5)	53.0	(46.7)	96.6	(79.4)
	Lisbon	52.7	(46.6)	83.4	(66.0)	99.1	(84.4)
42 days, after 1°C	Eureka	66.5	(54.7)	92.0	(73.6)	99.8	(87.6)
	Lisbon	86.0	(68.0)	99.3	(85.2)	100.0	(90.0)
+7 days 20°C	Eureka	70.2	(56.9)	93.3	(75.0)	100.0	(90.0)
	Lisbon	87.4	(69.3)	97.2	(80.3)	100.0	(90.0)
l.s.d. (P = 0.05) between 2 means:							
Same cultivar and storage time				(5.1)		(6.6)	(5.5)
Other combinations			(5.9)		(8.1)		(6.4)

Results and discussion

Chilling injury appeared as large (>1 cm^2) sunken lesions on the peel after low temperature storage which generally discoloured during storage at 20°C. Fruit stored continuously at 20°C did not develop chilling injury. Storage at 1°C for 14 days plus 20°C for 7 days led to the appearance of commercially unacceptable chilling injury in both cultivars (Table 1). Significantly more Lisbon than Eureka fruit were observed with moderate and severe injury. Storage for 28 and 42 days resulted in a significant increase in the incidence of chilling injury for both cultivars, with chilling injury observed immediately upon removal from 1°C (Table 1). The incidence of moderate and severe chilling injury was significantly greater in Lisbon compared with Eureka fruit. Storage at 1°C for 42 days with an additional 7 days at 20°C led to levels of injury in the 2 cultivars that were not significantly different.

The respiration rate of the 2 cultivars was determined during the week immediately after harvest, or following storage at 1 or 20°C for 14, 28 or 42 days (Fig. 1). Eureka and Lisbon lemons had similar respiration rates of 7 to 15 mg/kg.h when assessed after harvest. Cold storage for 14 days resulted in elevated respiration rates in both cultivars compared with continuous storage at 20°C, with peak respiration rates of 29 mg/kg.h for Lisbon and 22 mg/kg.h for Eureka lemons. Peak respiration rate occurred during the first 24 h, with respiration of Lisbon consistently higher than that of Eureka lemons. After 28 days at 1°C, peak respiration rate increased to 51 mg/kg.h for Lisbon and 34 mg/kg.h for Eureka. While respiration rates of both cultivars progressively decreased during the monitoring period, Lisbon was still at an elevated 29 mg/kg.h compared with 16 mg/kg.h in Eureka. After 42 days storage, peak respiration was higher than for any other storage time (73 mg/kg.h for Lisbon and 60 mg/kg.h for Eureka), which was consistent with the observations of extensive chilling injury.

The significantly higher respiration rate of cold-treated Lisbon lemons after 14, 28 and 42 days was consistent with our finding that Lisbon lemons were more susceptible to chilling injury than Eureka lemons. Elevation in peak respiration of cold-treated citrus after storage has been reported in grapefruit (McCollum and McDonald 1991), mandarin (Schirra and Mulas 1995) and orange (Mizuno and Taniguchi 1972). Most of the published work on respiration of cold-treated lemons relates to various pre-conditioning treatments (Hatton and Cubbedge 1982; Cohen *et al*. 1983; Bertolini *et al*. 1986).

Conclusions

Based on the incidence and severity of surface lesions and on respirational response, Queensland Eureka lemons are less susceptible to chilling injury than Lisbon lemons. The apparent lack of commercial success of exports of cold-disinfested Eureka lemons from the Burnett region (Queensland) compared with those from Victoria and South Australia is unlikely to be due specifically to differences in cultivar susceptibility to chilling injury. Previous work by McLauchlan *et al*. (1996) reported that chilling injury susceptibility in Queensland-grown Eureka lemons was influenced by de-greening, season and harvest date. The current

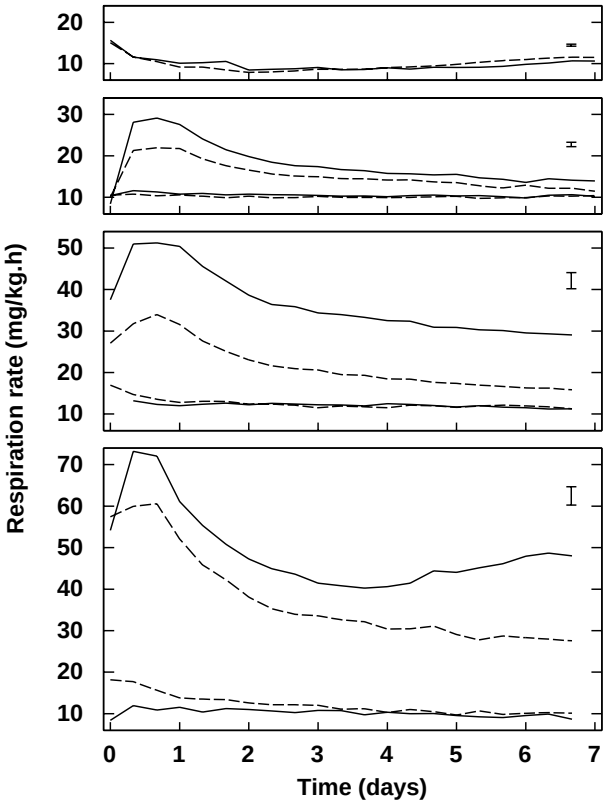

Figure 1. Respiration rates of cold treated (1°C) and ambient stored (20°C) 'Eureka' (dotted lines) and 'Lisbon' (solid lines) lemons following storage. Respiration rates were measured at 20°C. Control (non-stored) fruit (top); respiration rate of chilled (upper lines) and unchilled (lower lines) fruit after 14 days at 1 or 20°C respectively; respiration rate of chilled and unchilled fruit after 28 days at 1 or 20°C respectively; respiration rate of chilled and unchilled fruit after 42 days at 1 or 20°C respectively (bottom). Values represent the mean of 10 fruit (stored) or 20 fruit (non-stored). Vertical bars represent averages of the standard error of the means.

commercial problems associated with the cold-disinfestation of Queensland-grown Eureka lemons are more likely due to a combination of factors, possibly including pre-harvest conditions, than to cultivar.

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