Influence of Preharvest Sprays of Calcium Salts and Wax on Fruit Quality of Red Raspberry

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Abstract. Preharvest sprays of $CaCl_2$, $Ca(NO_3)_2$, or water soluble wax increased berry size (by wt) and decreased the rate of softening during storage for 48 hr at 21°C. In a split plot experiment, with 4 cvs. and 3 dates of harvest, preharvest sprays of wax increased firmness but had no effect on total acidity, acid loss, water loss, or fungal decay. There were, however, significant interactions between cvs. and harvest dates in relation to firmness, acidity, and rot development.

Declines in the local production of raspberries have been attributed to increased costs of harvesting and marketing losses associated with a high degree of perishability. For example, the limit of storage life is 2 to 3 days at 0°C (4). Increasing the concn of CO_2 up to 30% with the aid of dry ice retards the rate of softening and fungal growth (2, 5). With the development of mechanical harvesters there will be need for greater berry strength. Earlier work with strawberries indicated that sprays of Ca salts increased berry firmness (3).

We attempted to learn how the firmness of raspberries can be increased, and explored the physiological changes before and after harvest which determine the ultimate quality of the fruit.

Materials and Methods

Preliminary experiments in 1969 included preharvest sprays of $CaCl_2$ (0.4%), Ca $(NO_3)_2$ (0.6%), and (FMC 200) water soluble wax (25%) applied to 3-year-old 'Avon' raspberry plants 1 week before the first harvest. Applications were made to 12 plants in each treatment at intervals of 2 days with a total of 5 sprays of each of the Ca salts and 2 sprays containing wax. Successive harvests of 2 pint boxes of firm red berries from each plot were immediately stored at 0°C. After 24 hr, one box was placed at 21°C. From the other box, 10 uniform berries were selected for firmness measurements with a puncture tester (6). At room temp a probe 3 mm in diam, moving at 1 mm/sec was used to apply pressure to the dome end of the fruit until the druplet was pierced. The maximum force was recorded. Another 20 berries selected at random from the same box were weighed in order to determine if treatment affected berry size (by wt). After 48 hr at 21°C the second box was examined for decay development by number.

Fruit was harvested in 1970 from a 3-year-old experimental plantation which consisted of 4 randomized blocks containing cvs. Trent, Avon, Newburgh, and Canby planted in single row plots 10 bushes per 6.6 m plot. Half of each plot was sprayed with a water soluble (FMC 200) wax solution (25%) when the berries were at the "green pink" stage and again after the first of 3 harvests. Harvests were made 1 week apart commencing July 22, 1970. The fruit was measured using the 1969 procedure except that total titratable acidity and pH also were measured by macerating 100 g of fruit with an equal amount of water in a Waring blendor and titrating with 0.1 NaOH to a pH 8.1 endpoint. Acidity was calculated as citric acid % of fresh wt.

In 1971, 2 preharvest sprays, $CaCl_2$ and wax were applied at the times and concn applied previously to 3 replicates of plants of the seedling selection K65-12 ('Carnival' x 'Willamette'). Four dates of harvest were planned but due to heavy rains, which caused severe softening and dropping of over-ripe berries, the second and third harvests were eliminated Observations were confined to size by wt at harvest and rate of softening which was measured by shrinkage. A 600 ml beaker was filled to a depth of 100 mm and the depth of fruit was measured after storage for 48 hr at 21°C and an average R.H. of 60±8%. We have designated this method the "sink test."

Results

Firmness and loss of wt. Preliminary trials in 1969 indicated that coating berries and leaves on the bush with wax could maintain firmness (data not shown) during subsequent storage for 48 hr at 0°C. Sprays of Ca salts had no apparent effect upon firmness. In 1970 'Newburgh' and 'Avon' tended to be slightly more firm than 'Canby'. The berries of all cvs. from the second harvest were considerably firmer than those from the first or third harvests. Wax sprays resulted in an increase of 12.4% in firmness over unwaxed controls when data were pooled across cv. and harvests (Table 1).

Neither spray treatment nor harvest number affected wt loss after harvest but 'Canby' lost significantly more wt (2.23%) than 'Trent' (1.87%) ($P < .01$), 'Avon' (1.83%), and 'Newburgh' (1.83%) when held at 21°C for 48 hr.

$CaCl_2$ and wax sprays each reduced the amount of softening of fruit of the seedling selection K65-12 during storage. Wax sprays reduced the softening of the fruit more than $CaCl_2$ sprays did for fruit of the second but not the first harvest (Table 2).

Size of berries. Berries sprayed in 1969 with $CaCl_2$ and $Ca(NO_3)_2$ appeared to be larger than those non-sprayed. The average wt of berries were $CaCl_2$ 2.88 g, $Ca(NO_3)_2$ 2.20 g, and control 2.01 g (all significant at $P = .05$).

Significant increases in fruit wt at each of 2 harvests were associated in 1971 with both $CaCl_2$ and wax sprays (Table 3). As in the 1969 study, fruit of 'Canby' appeared to be softer than those of 'Trent', 'Avon', and 'Newburgh'.

Acid relationship. Sprays had no measurable influence upon fruit acidity. Except for fruit of 'Trent' from harvest 1 and 'Avon' from harvest 3, storage for 2 days at 21°C had no significant effect on acidity (Table 4). 'Canby' fruit contained the lowest total acid only at harvest 3. 'Trent' was the only cv. whose fruit's acid content increased significantly from the first to the third harvest.

There were no significant differences between cvs. or treatments in pH, but it tended to decrease from early to late harvests. The pH's of harvests 1, 2, and 3 were 3.17b, 3.13b, and 3.05a, respectively.

Fruit rot. In 1969, fruit not sprayed had the most decay (22.7%). Sprays of wax (18.2% decay) or $CaCl_2$ (12.6% decay) significantly reduced decay. Fruits sprayed with $Ca(NO_3)_2$ had a lower rate of decay (11.2%) than those of any other

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Table 1. Influence of cv., date of harvest, and preharvest wax spray on firmness of raspberries after storage at 0°C for 24 hr.

cv.	g/cm²	Harvest	g/cm²	Treatments	g/cm²
Newburgh	26.53a[z]	1.	20.11a	Waxed	23.77b
Avon	23.83a	2.	27.34b	Unwaxed	20.73a
Trent	21.11ab	3.	19.31a		
Canby	18.36bc				

[z]Values followed by the same letter in a given column were not significantly different at 1% level.

Table 2. Influence of $CaCl_2$ and (FMC 200) wax preharvest sprays on softening of raspberries (expressed as a decrease in depth from 100 mm after 48 hr at 21°C).

Treatment	Harvest 1 decrease mm	Harvest 2 decrease mm
$CaCl_2$ 0.4%	5a[z]	11b
Wax 25%	6a	8a
Control	11b	15c

[z]Values followed by the same letter in a given column are not significantly different at 1% level.

Table 3. Influence of $CaCl_2$ and wax preharvest sprays on the wt of raspberries at harvest.

Treatment	Harvest 1 wt g	Harvest 2 wt g
$CaCl_2$ 0.4%	1.62a[z]	1.66a
Wax 25%	1.77a	1.75a
Control	1.39b	1.50b

[z]Values followed by the same letter in a given column were not significantly different at the 1% level.

Table 4. Influence of cv. and date of harvest on acid content (as % citric acid, fresh wt) of raspberries at harvest and after storage for 48 hr at 21°C.

	1st Harvest		2nd Harvest		3rd Harvest	
Cvs.	At harvest	After storage	At harvest	After storage	At harvest	After storage
Trent	1.89b[z]	1.79a	1.91b	1.77b	2.08c	1.90c
Avon	1.96b	1.87b	1.88b	1.76b	1.92b	1.83c
Newburgh	1.89b	1.74b	1.91b	1.73b	1.73b	1.66b
Canby	1.61a	1.69a	1.40a	1.42a	1.28a	1.09a

[z]Values followed by the same letter in a given column were not significantly different at the 1% level.

treatment. No significant effects on decay were found with wax in 1970 or with either wax or $CaCl_2$ in 1971. The decay was caused mainly by *Botrytis cinerea* Pers. with a few minor rots due to *Rhizopus* sp. and *Cladosporium herbarium* Lk.

The least amount of decay developed in fruits of 'Newburgh'. The incidence of decay tended to increase as the season progressed (Table 5).

Table 5. Influence of cvs. and time of harvest on the decay of red raspberries stored for 48 hr at 21°C.

Cvs.	Decay %	Harvest	Decay %
Trent	21.0b[z]	1	22.1a
Newburgh	17.6a	2	27.1a
Avon	22.5b	3	37.1b
Canby	25.2b		

[z]Values followed by the same letter in a given column were not significantly different at the 5% level.

Discussion

Preharvest sprays of Ca salts or wax appeared to have a beneficial effect on size and firmness of raspberry fruit as well as on rate of softening during storage. Sprays of Ca salts tended to reduce fungal rots during storage at 21°C for 48 hr.

The type of cv. and time of harvest exerted major influences on quality. For example, 'Canby' fruit was softer and less acidic, and lost more wt when held for 48 hr at 21°C than did fruit of 'Trent', 'Avon' or 'Newburgh'. On the other hand, 'Trent' was the only cv. for which the total acidity of fruit increased as the harvest season progressed. This may be of importance to marketing since the acid composition of fruit juices has been reported to afford a mechanism for resistance to decay-producing organisms (1).

Fruits of 'Newburgh' and 'Avon' were much firmer than those of 'Canby'. The berries from all cvs. at the second harvest were approx 25% firmer than those harvested either a week earlier or later. This could be important in a "once over" mechanical harvesting operation. The substantial decrease in the rate of softening of raspberries after harvest by the use of preharvest sprays should further reduce losses.

Berry wt increases over control fruit associated with applications of $CaCl_2$ and wax were in the order of 25%. They have potential economic importance giving greater returns per acre, and they should result in greater marketable yields per acre. Since there was less water loss after harvest in wax treated berries at 21°C, it is suggested that the size increase was due to a reduction in the rate of transpiration from the leaves and berries before harvest as well as a decrease in rapid transpiration of berries, which occurs when warm berries are placed in a 0°C environment.

Variability in the pressure test (firmness) results (1969) was ascribed to slight differences in maturity, improper alignment of the berry with the probe, and obstruction by the seeds. The simplicity of the "sink test" and the significant response suggests that modification of it probably could provide a more rapid "on the spot" test for firmness than the 48 hr test we used.

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