Control of Woolly Breakdown of 'Elberta' Peaches in Cold Storage, by Intermittent Exposure to Room Temperature[1]

Ruth Ben-Arie, S. Lavee and Sylvia Guelfat-Reich
Volcani Institute of Agricultural Research
Bet Dagan, Israel

Abstract. Control of woolly breakdown in 'Elberta' peaches was obtained by removal of the fruit to ambient room temperature (23–25°C) for 48 hours after 2 and 4 weeks' storage at 0°C. A 6 weeks' storage life was thus obtained. Warming the fruit after cold storage intervals shorter than 2 weeks was less effective after longer storage periods; the disorder was often enhanced by removal to room temperature.

A hypothesis to explain the development of woolly breakdown on the basis of these and previous data is discussed. It is suggested that further prolongation of storage could be obtained by repeated exposures to room temperature.

The storage life of 'Elberta' peaches at 0°C is usually limited to 2 weeks, because of the occurrence of woolly breakdown (2). By holding the fruit at 23°–25°C for 2–4 days before storage at 0°C, the onset of the disorder was delayed, and a 2 week increase in storage life was obtained (2, 4, 5). Delayed storage treatment is less effective if the fruit is harvested at fully ripe stage of maturity (6).

Pentzer and Heinze (7) advanced the hypothesis that the occurrence of chilling injury in fruits is the result of a deviation in the equilibrium between 2 types of reaction taking place in the cells, a) the accumulation and b) the breakdown of toxic substances. At the critical temperature specific to each cultivar, the rate of both reactions is equal, but below this temperature the accumulation of toxic substances is more rapid than their breakdown, causing injury to the tissues. Evidence for this theory is the work of Smith (9, 10). He controlled superficial scald of apples and low temperature injury of plums, by transferring the fruit during storage from low temperatures to room temperature, for 5 days and 24 hours, respectively. In view of this work, and the finding that major chemical changes associated with the occurrence of woolliness in peaches stored immediately at 0°C were detectable only after 2 weeks of cold storage[2], it was thought that intermittent exposure of the fruit to higher temperatures at intervals of 2 weeks might be more effective than delayed cold storage in controlling this physiological disorder.

Materials and Methods

'Elberta' peaches were harvested from a commercial orchard at "ripe" stage. The harvest data for fruit were defined as follows: ground color, green-yellow [plates 261 and 225 according to Séguy's color chart (8)]; firmness, 5–6 lbs with a 7/16 inch tip on a Magness-Taylor pressure tester; total soluble solids (T.S.S.), 13.5–14.5% with a hand refractometer; and a respiration rate (3) of 80–90 mg CO_2/kg/hr at harvest, reaching a climacteric peak of 100–130 within 2–3 days at 20°C (3). The fruit was either held for 60 hrs at room temperature prior to storage at 0°C, or stored immediately at 0°C and subsequently exposed to room temperature for 48 hrs., after various intervals.

Fruit from each treatment were finally removed to room temperature once a week from the third week of storage, and examined after an additional 2 days' shelf-life. The fruit pulp was classified as healthy, reddened or woolly. Pulp reddening and woolliness were graded as light, medium or severe; the indices for each were calculated as follows:

$$\text{Pulp reddening index} = \frac{\text{LD} + 2.\text{MD} + 3.\text{SD}}{10}$$

$$\text{Woolly breakdown index} = \frac{2.\text{LD} + 3.\text{MD} + 4.\text{SD}}{10}$$

where LD = % fruit with light damage
MD = % fruit " medium "
SD = % fruit " severe "

Each treatment consisted of 4 replicates of 20 fruits at each examination.

Results and Discussion

A marked decrease of woolly breakdown in 'Elberta' peaches was obtained by removing the fruit after 5, 10, 15 days from 0°C to room temperature for 48 hrs. Examination of the fruit after 3 and 4 weeks storage showed a noticeable increase in percentage of healthy fruit as the time of exposure was deferred (Fig. 1). The recommended delayed storage treatment was not effective (Table 1) due to the "ripe" stage of maturity of the fruit in this experiment, which is known to be especially susceptible to woolly breakdown (6). By intermittent exposure to room temperature the control of the disorder even in this fruit was considerable.

The fact that the optimum time for exposure to room temperature occurs shortly before the appearance of the initial symptoms of woolliness, suggests that the disorder is the result of a 2-stage process. According to this hypothesis, a certain process takes place in the fruit during the first fortnight of storage at 0°C. Its intensity depends on the cultivar and the stage of maturity of the cultivar (6). The cumulative effects of the process can be reversed by transferring the fruit to temperatures above critical for normal ripening. The process of the second stage, which is a result of the accumulated effects of the first, is manifest in the altered metabolism of the pectic substances (1) and the occurrence of woolly breakdown. These processes are irreversible and a transfer of the fruit at this stage to higher temperatures, as during shelf-life,

[1]Received for publication May 18, 1970. Contribution from the Volcani Institute of Agricultural Research, Bet Dagan, Israel. 1970 Series, No. 1714-E.

[2]Ben-Arie, Ruth (1969) Woolly Breakdown of Peaches in Cold Storage. Ph.D. thesis submitted to the Hebrew University of Jerusalem. (In Hebrew, with English summary)

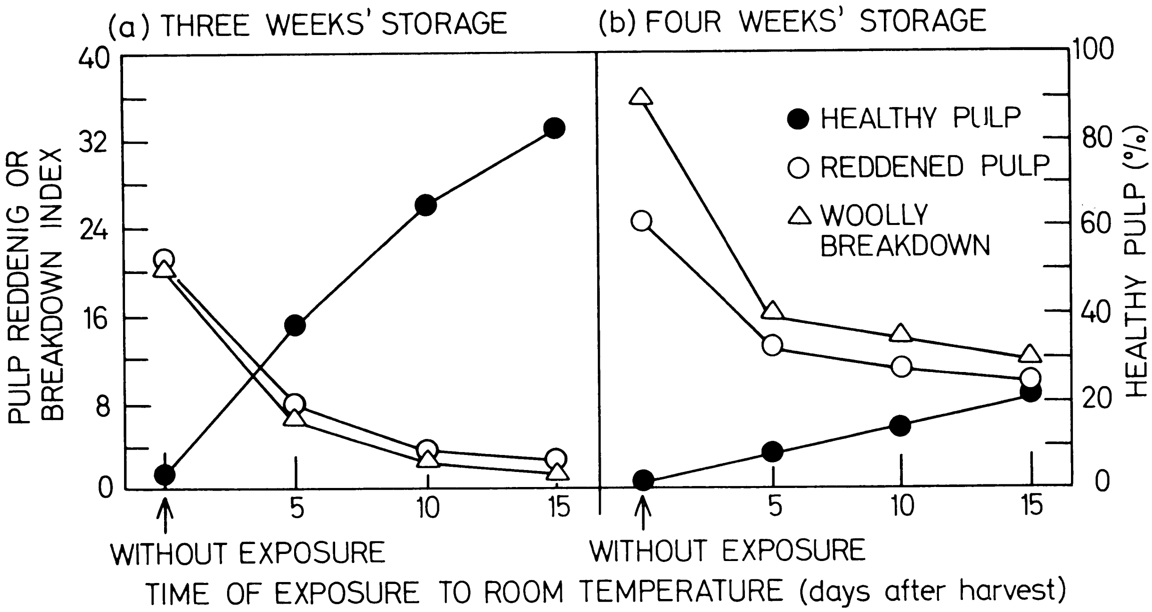

Fig. 1. The effect of 48 hours' exposure to room temperature at various times during cold storage, on the keeping quality of 'Elberta' peaches.

only hastens the onset of woolliness and enhances its severity.

If this hypothesis is correct, it should be theoretically possible to prevent the onset of woolliness indefinitely by repeatedly exposing the fruit to room temperatures just before the termination of the first stage, and returning it for the critical period to 0°C to inhibit further ripening. The storage life of the peach would then be limited by the degree of ripeness attained, and not by woolly breakdown. The results of an experiment conducted to examine this possibility are presented in Table 2. Though the process of woolly breakdown was not entirely curtailed by 2 repeated exposures to room temperature, the fruit suffered, after 6 weeks' storage, mainly from reddening, with even less woolly breakdown and more healthy tissue than in fruit from the delayed storage treatment after 4 weeks' storage. The fruit from the double-exposure treatment was still firm and not overripe after 6 weeks' storage plus 2 days' shelf life. It is possible that 48 hours' exposure to room temperature was insufficient and that a slightly longer exposure time would have been more effective.

Though data concerning the nature of the processes occurring during the second stage have been reported and an explanation for the mechanism which finally induces woolliness in peaches offered (1), the nature of the process operating in the first stage is still unknown. It seems possible that this factor might be common to many fruits susceptible to different types of chilling injury. Smith in work with apples and plums (9, 10), infers that there is an optimal time for exposure of the fruit to high temperatures, and if the length of the storage period following exposure at this optimal time exceeds that preceeding it, injury symptoms begin to appear. According to the hypothesis presented here, this would mean that the factor in the first stage had again accumulated sufficiently to put into operation the second stage process, which manifested itself as injury to the fruit tissues.

Table 1. The effect on the keeping quality of 'Elberta' peaches by exposure to room temperature after 2 weeks' storage at 0°C, vs. no exposure and delayed storage.

Treatment	Duration of storage (weeks)	Non-woolly fruit (%)	Pulp reddening index	Woolly breakdown index
Immediate storage at 0°C	3	5.0	13.7	2.5
	4	1.9	16.5	16.7
60 hours at room temperature before storage at 0°C (delayed storage)	3	26.2	13.7	0
	4	4.8	8.9	16.4
48 hours at room temperature after 2 weeks at 0°C	3	92.4	0.4	6.7
	4	82.2	1.3	3.5

Table 2. The effect of repeated exposures to room temperature on the keeping quality of 'Elberta' peaches stored at 0°C.

Treatment	Duration of storage (weeks)	Non-woolly fruit (%)	Pulp reddening index	Woolly breakdown index
60 hours at room temperature before storage at 0°C	4	43.7	6.0	3.1
	5	2.5	13.6	27.6
48 hours at room temperature after 2 weeks at 0°C	5	22.0	15.0	2.8
	6	0	14.7	22.5
48 hours at room temperature repeated at 2 and 4 weeks after harvest	5	80.0	2.7	0
	6	60.0	4.2	1.2

Literature Cited

1. Ben-Arie, Ruth and S. Lavee. Pectic changes occurring in Elberta peaches suffering from woolly breakdown. *Phytochemistry*. (in Press)
2. Boyes, W. W. 1955. The development of woolliness in South African peaches during cold storage. *IX Int. Cong. du Froid, Paris* 4:533–537.
3. Claypool, L. T. and R. M. Keefer. 1942. Colorimetric method for CO_2 determination in respiration studies. *Proc. Amer. Soc. Hort. Sci.* 40:177–186.
4. Davies, R., W. W. Boyes, and D. J. R. de Villiers. 1938. Delayed storage of Peregrine peaches. *Low Temp. Res. Lab. Capetown, Ann. Rpt.* 1937–38:51–53.
5. Fisher, D. V., J. E. Britton, and H. S. O'Reilly. 1943. Peach harvesting and storage investigations. *Sci. Agr.* 24:1–16.

J. Amer. Soc. Hort. Sci. 95(6): 801–803. 1970.

6. Guelfat-Reich, Sylvia and Ruth Ben-Arie. 1966. Effect of delayed storage and the stage of maturity at harvest on the keeping quality of peaches in Israel. *Israel J. Agr. Res.* 16:163–170.
7. Pentzer, W. T. and P. H. Heinze. 1954. Postharvest physiology of fruits and vegetables. *Ann. Rev. Plant Physiol.* 5:205–244.
8. Séguy, E. 1936. Code Universel des Couleurs, Encyclopedie Practique du Naturaliste. Paul Lechavalier, Paris.
9. Smith, W. H. 1947. Control of low temperature injury in the Victoria plum. *Nature* 159:541–542.
10. ————. 1959. Control of superficial scald in stored apples. *Nature* 183:760.

Effect of Three Soil Moisture Regimes on the Growth and Anatomy of *Pelargonium hortorum*[1,2]

A. W. Metwally, B. Esther Struckmeyer and G. E. Beck
University of Wisconsin, Madison

Abstract. 'Dark Red Irene' and 'Princess Irene' geraniums were subjected to low, medium, and high soil moisture regimes in the greenhouse for 10 weeks. A system was devised to maintain 3 moisture levels. Plant height, leaf area, and dry weight increased as soil moisture increased. Diameter of petioles and stems and thickness of leaves also increased as soil moisture increased. Number of xylem elements per unit area increased considerably in stems and petioles of plants grown in the high moisture regime, while phloem tissue was greater in plants grown in medium moisture. More vascular bundles were differentiated in leaves per unit as soil moisture decreased. 'Princess Irene' had fewer xylem and more phloem elements than 'Dark Red Irene', especially in plants grown in high soil moisture.

Water is an essential factor in plant life. Adequate water and turgor pressure are necessary for cell enlargement, for regulation of gas exchange between leaves and atmosphere, and for other physiological processes within the plant. Reports on the influence of different soil moisture contents on plant growth are numerous compared to investigations on the anatomical structure of plants exposed to different soil moisture regimes.

In dry soil, root weight/shoot weight ratio was greater than in wet soils (12). The height of plants increased as soil moisture increased. Penfound (8) reported that the average leaf area of sunflower plants grown in wet soil was more than 12 times that of plants grown in dry soil. Similar results were reported with geraniums (1) and tobacco (5). In *Trifolium incarnatum* the total dry weight and leaf weight increased by increasing soil moisture from 40% to 60% (12). Salter (11), working with tomatoes, reported more growth as reflected by dry weight under the low moisture tension; however, there was not a proportional increase in yield of fruit.

Penfound (8) discovered that stems of plants grown in soil with high water content had more and larger xylem vessels, larger cells, and thicker-walled fibers than did comparable plants grown in soil with low water content. In leaves, he found a greater width of all regions in the mesophyll and midvein so that leaves were thicker with high soil moisture than with low soil moisture.

Amer and Williams (1) reported that leaves of geranium plants growing in dry soil had smaller epidermal cells and more cells per unit area than those grown in wet soil, but they observed very little difference in number of cells on a 'per leaf' basis. Stocker (12) concluded that leaves grown on plants in dry soil developed smaller epidermal and mesophyll cells than leaves on plants in a moist habitat. However, the length of veins, the number of veins, the number of veins per unit area of leaf surface, the thickness of the outer walls of the epidermal cells, the development of mechanical tissues, and the formation of a typical palisade layer were increased in the dry habitat.

Excessive water was shown by Balge et al. (2) to cause physiological disorders of geranium. They showed that geranium cultivars responded differently to high soil moisture levels. Severity of oedema was considerably higher in 'Dark Red Irene' ('DRI') than in 'Princess Irene' ('PI') in wet soil. This study was conducted to obtain additional information on responses of those 2 cultivars to 3 soil moisture regimes to aid in understanding geranium behavior in relation to oedema.

Materials and Methods

Two cultivars, DRI and PI, were used because of their known differences in response to soil moisture regimes (2). Rooted cuttings were planted in 4-inch plastic pots using a medium composed of 2 parts silty loam soil, 1 part horticultural peat, and 1 part horticultural perlite.

A system to maintain 3 soil moisture regimes was developed utilizing the fiberglass wick watering method described by Post (9). The 4-inch plastic pots had a hole large enough to accommodate a .94 cm diameter fiberglass wick. Five cm of the wick were raveled; the nonraveled portion was inserted and pulled down through the hole in the bottom of the pot. The soil medium was then added and the raveled end of the wick was arranged within the pot to supply moisture to the medium. The nonraveled end of the wick was placed in water maintained at a constant level. Plexiglass tubes 7.5 cm tall and 2 cm in diameter served as water containers and were connected in series at the bottom using .47 cm T-shaped glass and rubber tubing. The plexiglass tubes were placed vertically at 30 cm intervals. The moisture content of the medium was governed by the distance from the bottom of the pot to the water surface, which was

[1]Received for publication May 4, 1970, published with the permission of the Director, Research Programs Division, College of Agricultural and Life Sciences, Madison, Wisconsin. These investigations were conducted in partial fulfillment of the requirements for the Ph.D. degree by the senior author, University of Wisconsin.
[2]The authors thank T. W. Tibbitts for his helpful suggestions and Yoder Brothers, Inc., Barberton, Ohio for their generous donations of some of the plant materials.