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Fruit Firmness, Calyx and Neck Ratings Correlated with Field Fruit Rot Reactions of Nine Strawberry Cultivars

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Abstract

Fruit calyxes and necks were rated, and fruit epidermis toughness and flesh firmness were measured, for nine strawberry (*Fragaria* x *ananassa*) cultivars on four harvest dates during 1991. These data were correlated with percent of fruit with each of several rot diseases at harvest in 1991 and 1992. The cultivars differed significantly for all traits. 'Earliglow' and 'Tristar' had the most reflexed calyxes, and 'Earliglow' and 'Cardinal' had the most raised necks. 'Cardinal' and 'Allstar' had the greatest fruit flesh firmness and epidermis toughness. Greater fruit epidermis toughness did not correlate well with reduced levels of any fruit rot. Greater fruit flesh firmness correlated significantly, although not highly ($r = 0.26$ to 0.37), with reduced anthracnose fruit rot (caused by *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc.), leather rot (incited by *Phytophthora cactorum* (Leb. & Cohn) Schrot.), and total rots during both years, but not with reduced gray mold (caused by *Botrytis cinerea* Pers.:Fr.). Mid-season calyx ratings correlated significantly ($r = 0.39$ to 0.50) with reduced leather rot, anthracnose and total rots during one year each. Both mid-season neck ratings, and the mean of mid-season calyx and neck ratings, correlated significantly ($r = 0.37$ to 0.62) with reduced levels of all rots during both years, except for leather rot in 1992. Overall, the mid-season calyx-neck mean predicted rot levels the best of the fruit traits studied.

Introduction

Strawberry fruit firmness is an important component of fruit quality (4, 8, 11), especially when berries are shipped long distances to fresh markets, and for processing markets. Processing markets also require berries with raised necks and reflexed calyxes to minimize cutting waste (4). Strawberry cultivars and genotypes vary in these characteristics (4, 8, 11), and several researchers have suggested that these traits may also influence fruit rot susceptibility (1, 2, 3, 9; Gene Galletta, personal communication).

Strawberry fruit rots, especially anthracnose fruit rot (incited by several *Colletotrichum* species), leather rot (caused by *Phytophthora cactorum*), and gray mold (incited by *Botrytis cinerea*), often cause severe pre- and postharvest losses (5). Greater fruit firmness at maturity has often been associated with less postharvest susceptibility to gray mold (1, 2, 3, 12), but strawberry clones with firmer fruit are not necessarily more resistant to gray mold before harvest (1, 9), and certain cultivars with softer fruit have also displayed low percentages of several fruit rots during storage (12). Two components of fruit firmness, epidermis toughness and flesh firmness, are not always related in strawberries (8), and one might increase gray mold resistance more than the other. No studies on any association between fruit firmness and resistance to anthracnose fruit rot or leather rot, nor between calyx or neck ratings and resistance to any rot, have been reported.

We conducted this study to determine the extent of variation among nine strawberry genotypes for epidermis toughness, flesh firmness, and calyx and neck ratings, and to determine if correlations exist between any of these fruit traits and pre- or postharvest resistance to any prevalent fruit rot disease.

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Materials and Methods

A strawberry field was planted in June 1990 at the University of Arkansas Experimental Farm in Fayetteville, and berries were harvested in May 1991 and May 1992, as detailed in Study 1 of (7). The field included eight replicated blocks of nine strawberry cultivars chosen to provide a range of susceptibility to fruit rots: 'Allstar,' 'Cardinal,' 'Earliglow,' 'Fern,' 'Guardian,' 'Lateglow,' 'Sunrise,' 'Tristar,' and 'Yolo.'

On four harvest dates during 1991 (3 May, 10 May, 16 May, and 28 May), samples of sound, ripe fruit were taken from each plot for calyx and neck ratings and skin toughness and flesh firmness measurements. At least 32 berries per cultivar were rated for calyx and neck on each date, and at least 24 of the same berries per cultivar were measured for epidermis toughness and flesh firmness on each date. The five-level calyx and neck rating system of Khanizadeh et al. (4) was used, with 1 = clasping calyx or sunken neck, 2 = slightly clasping calyx or slightly sunken neck, 3 = level calyx or neck, 4 = slightly reflexed calyx or slightly raised neck, and 5 = reflexed calyx or raised neck (Fig. 1). The highest levels of calyx and neck ratings are the most desirable. The calyx-neck mean was also computed as the mean of the two ratings for each berry, as a value that would include both traits and might correlate better with fruit rot resistance than either trait alone.

Fruit firmness was measured with an Omega digital force gauge with a 5-mm, blunt-end probe, operating at 1.23 mm/sec. Epidermis toughness was measured on one intact side of each berry at its widest diameter, and flesh firmness was measured on the opposite side after a thin slice, including the epidermis, had been removed. Fruit firmness measurements for each cultivar did not differ among the last three harvest dates. A heavy rain several

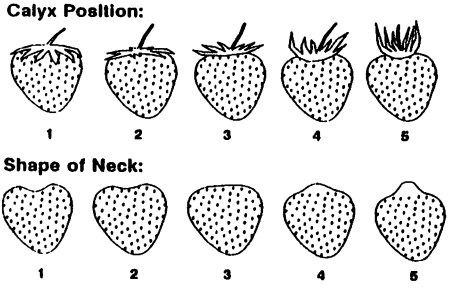

Figure 1. Classification of strawberry fruit by rating scale of Khanizadeh et al. (1991) for calyx position and shape of neck: 1 = least desirable, 5 = most desirable. Calyx rating scale: 1 = clasping, 2 = slightly clasping, 3 = level, 4 = slightly reflexed, 5 = reflexed. Neck rating scale: 1 = sunken, 2 = slightly sunken, 3 = level, 4 = slightly raised, 5 = raised.

hours before the first harvest apparently increased fruit cell turgor pressure to maximum levels, because both epidermis toughness and flesh firmness values for each cultivar were about twice as high on this date as on the other three dates. Firmness data from the first harvest date were therefore excluded from the analysis.

Seasonal-total percentages of sound fruit and those with each rot disease were computed for each plot during each year. Analyses of variances were performed for each fruit trait and percentages of fruit with each rot disease using the Statistical Analysis System general linear model procedure (10). No data transformations were needed. Means were separated using Duncan's multiple range test, and Pearson correlation coefficients (r values) were determined for pairs of fruit traits from 1991 data and field rot percentages from both years. Strawberry fruit firmness, calyx and neck ratings varied only slightly from year to year during a three-year study (4) and a five-year study (12). Therefore, the 1991 means for these traits should be typical of each cultivar, and correlations of these traits measured in 1991 with fruit rot data from 1992 as well as 1991 should be sufficiently accurate.

Table 1. Mean fruit calyx and neck ratings from two mid-season harvests for nine strawberry cultivars, 1991.[z,y]

Cultivar	Mean calyx rating	Mean neck rating	Calyx-neck mean
Earliglow	2.81 a	3.69 a	3.25 a
Cardinal	2.31 b	3.67 a	2.99 b
Tristar	2.81 a	3.08 b	2.94 bc
Sunrise	2.45 b	3.05 b	2.75 cd
Guardian	1.93 c	3.20 b	2.57 de
Allstar	1.94 c	3.06 b	2.50 ef
Yolo	2.30 b	2.33 d	2.32 fg
Lateglow	1.59 d	2.78 c	2.19 g
Fern	2.19 bc	2.06 e	2.13 g

[z]Rating system: 1 = clasping calyx or sunken neck, 2 = slightly clasping calyx or slightly sunken neck, 3 = level calyx or neck, 4 = slightly reflexed calyx or slightly raised neck, 5 = reflexed calyx or raised neck.
[y]Each value listed is a mean of 52 to 64 berries over two midseason harvests (10 May and 16 May). Means followed by different letters differ significantly according to Duncan's multiple range test, $P = 0.05$.

Results and Discussion

Anthracnose and leather rot exerted moderate disease pressure in 1991 and heavy pressure in 1992, while gray mold levels were very low in 1991 and moderately low in 1992. Cultivars differed significantly for percentages of all rot diseases at harvest during both years (7), but gray mold levels during 1991 were too low to provide meaningful correlations with fruit characters.

Mean fruit calyx ratings decreased over the harvest season for all cultivars except 'Guardian,' with especially steep drops for 'Cardinal' and 'Earliglow' (Fig. 2). 'Earliglow' had the highest calyx ratings for the first two harvest dates but dropped below ratings for 'Tristar' on the last two harvest dates. On the last two harvest dates, when 'Lateglow' was harvested, it had the lowest calyx ratings, despite the fact that its primary and secondary berries were ripe, while tertiary and quartenary berries of the early cultivars were ripe. Perhaps the progression from primary to quartenary berries, or rising temperatures over the harvest season, influences the decline in calyx ratings. Calyx ratings were lower in this study than in that of Khanizadeh et al. (4) for the same cultivars, which may be partly due to warmer temperatures in Arkansas than in Quebec. 'Earliglow' and 'Annapolis' had the highest calyx ratings in the Quebec study (4).

Mean fruit neck ratings remained stable over the season, except for three cultivars on the last harvest date (Fig. 3). 'Allstar,' 'Cardinal,' and 'Guardian' had significantly higher neck ratings on the last harvest date than on the other harvest dates, but ratings for the

Table 2. Mean fruit epidermis toughness and flesh firmness measurements for nine strawberry cultivars, 1991.[z,y]

Cultivar	Epidermis toughness (Newtons)	Flesh firmness (Newtons)
Cardinal	1.61 a	0.95a
Allstar	1.45 b	0.77 b
Tristar	1.20 cd	0.63 c
Earliglow	1.30 c	0.60 cd
Lateglow	1.20 cd	0.53 cde
Sunrise	1.05 e	0.51 de
Yolo	1.31 c	0.48 e
Guardian	1.07 de	0.45 e
Fern	1.04 e	0.45 e

[z]Measurements made with an Omega digital force guage, 5 mm blunt end probe at 1.23 mm/sec.
[y]Each value listed is a mean of 68 to 80 berries over three harvests (10 May, 16 May and 28 May). Means followed by different letters differ significantly according to Duncan's multiple range test, $P = 0.05$.

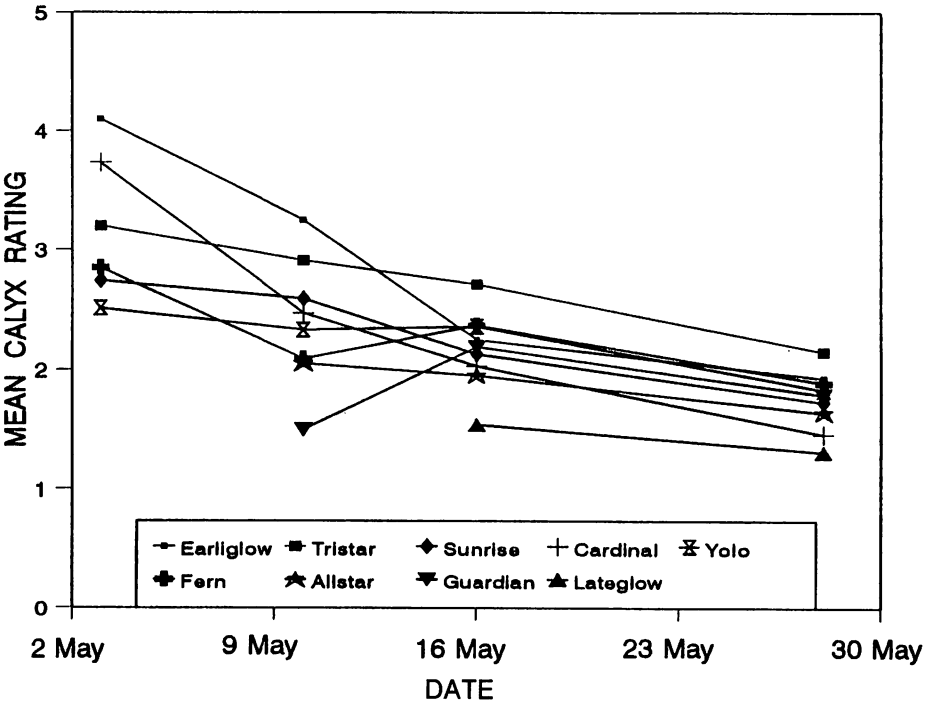

Figure 2. Mean fruit calyx ratings on four harvest dates for nine strawberry cultivars, Fayetteville, AR, 1991. Calyx rating scale: 1 = clasping, 2 = slightly clasping, 3 = level, 4 = slightly reflexed, 5 = reflexed.

other six cultivars did not differ with harvest date. 'Earliglow' and 'Cardinal' had the highest neck ratings, while 'Fern' and 'Yolo' had the lowest ratings (Table 1). Neck ratings were also somewhat lower in this study than in that of Khanizadeh et al. (4) for the same cultivars. 'Earliglow' and 'Allstar' had the highest neck ratings in that study, which did not include 'Cardinal.'

Epidermis toughness and flesh firmness measurements remained stable over the season, except when berries were harvested immediately after a heavy rain as noted above. Epidermis toughness and flesh firmness were highly correlated in these cultivars (r = 0.79). Rankings of the cultivars from most to least firm were very similar for epidermis toughness and flesh firmness (Table 2) except for 'Yolo,' which had moderate epidermis toughness but low flesh firmness. 'Cardinal' had the most firm fruit, followed by 'Allstar,' while 'Fern,' 'Guardian,' 'Sunrise' and 'Yolo' had the least firm fruit.

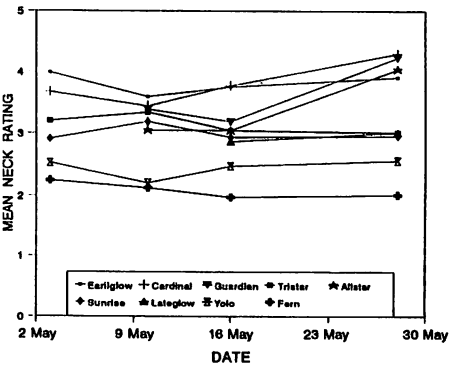

Figure 3. Mean fruit neck ratings on four harvest dates for nine strawberry cultivars, Fayetteville, AR, 1991. Neck rating scale: 1 = sunken, 2 = slightly sunken, 3 = level, 4 = slightly raised, 5 = raised.

Table 3. Pearson correlation coefficients for fruit traits with percent fruit rots at harvest in eight replications of nine strawberry cultivars, 1991.

Fruit trait	Correlation coefficient (r value)		
	Anthracnose fruit rot	Leather rot	Total rot
Epidermis toughness	-0.03	-0.25*	-0.13
Flesh firmness	-0.26*	-0.27*	-0.33**
Mid-season calyx	-0.11	-0.38*	-0.31
Mid-season neck	-0.47**	-0.44**	-0.61****
Calyx-neck mean	-0.39*	-0.55***	-0.62****

*, **, ***, **** Significant at $P = 0.05$, 0.01, 0.001, or 0.0001, respectively.

Greater flesh firmness correlated significantly, although not highly (r = 0.26 to 0.37), with reduced anthracnose, leather rot and total rot at harvest in both years, but not with reduced gray mold in 1992 (Tables 3, 4). Epidermis toughness did not correlate significantly with rot reaction except to leather rot in 1991 and total rot in 1992, and then only slightly. Apparently, firm flesh inhibits preharvest rot growth more than a tough epidermis, although neither provides much protection against preharvest fruit rots.

Very low correlation coefficients of 0.05 to 0.08 between calyx and neck ratings, and between either calyx or neck rating with epidermis or flesh firmness, indicate that these fruit characteristics are not often associated. Khanizadeh et al. (1991) found no significant correlation between strawberry calyx or neck ratings and fruit firmness, and a 0.49 correlation between reflexed calyx and raised neck was significant only at the $P = 0.10$ level.

Mid-season calyx and neck ratings from the middle two harvests were deemed most representative and used to compute correlations with seasonal-total percentages of fruit with each rot disease at harvest. Mid-season calyx ratings correlated significantly (r = 0.38 to 0.50) with reduced leather rot, anthracnose and total rots during one year each. Both mid-season neck ratings and the mean of midseason calyx and neck ratings correlated significantly (r = 0.37 to 0.62) with reduced levels of all rots during both years, except for leather rot in 1992 (Tables 3, 4).

Overall, the mid-season calyx-neck mean predicted rot levels the best of the fruit characters studied. Calyx and neck ratings were both highest for 'Earliglow', the most rot-resistant cultivar, but diverged for other cultivars. Taking the mean of calyx and neck ratings allowed the two to cancel each other when they conflicted and reinforce each other when they concurred. Many other factors influence

Table 4. Pearson correlation coefficients for fruit traits measured in 1991 with percent fruit rots at harvest in eight replications of seven strawberry cultivars, 1992.

Fruit trait	Correlation coefficient (r value)			
	Anthracnose fruit rot	Leather rot	Gray rot	Total rot
Epidermis toughness	-0.22	-0.23	-0.15	-0.28*
Flesh firmness	-0.30*	-0.30*	-0.15	-0.37**
Mid-season calyx	-0.50**	-0.08	-0.28	-0.46**
Mid-season neck	-0.49**	-0.25	-0.37*	-0.54**
Calyx-neck mean	-0.61***	-0.18	-0.39	-0.61****

*, **, ***, Significant at $P = 0.05$, 0.01, or 0.001, respectively.

fruit rot susceptibility in strawberries, but selecting for berries with raised necks, reflexed calyxes, and greater flesh firmness should help provide some rot resistance as well as qualities needed for shipping or processing.

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Stone Fruit Breeding in Lithuania

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Abstract

European plum *(Prunus domestica)*, sour cherry *(Prunus cerasus)*, sweet cherry *(Prunus avium)*, apricot *(Prunus armeniaca)* — in that order — are widely grown in Lithuania, but varieties are restricted due to cyclical cold winters (-35°C) every 11-12 years. Varieties introduced from more southern regions are injured by cold, but they have high quality fruit. Local selections or varieties from colder regions are hardy, but have medium quality fruit. In 1952 a breeding program was begun at the Vytėnai Experimental Station (reorganized 1987 as Lithuanian Institute of Horticulture) to develop reasonably hardy, disease resistant, high yielding, high quality varieties. The following varieties of European plum, sour cherry, and sweet cherry have been released.

European Plum

'Štaro Vengrinė' ('Ankstyvoji Vengrinė' op) introduced in 1962 by I. Štaras and A. Lukoševičius. Ripens mid-August. Fruit elliptical, 30-35 g, attractive, tasty, sweet, aromatic. Skin violet with bluish-grey bloom, flesh yellowish, firm, juicy. Stone, 1.2g, easily removed. Tree moderate grower, medium hardy, medium resistant to fungal diseases such as *Sclerotinia laxa, Clasterosporium carpophilum* and bears in the orchard within three or four years.

'Orija' ('Renklod Kolchoznyj' op) introduced in 1972 by A. Lukoševičius and G. Šviriené. Ripens end of August. Fruit round, 40-50g, freestone, attractive, very tasty, sweet, aromatic. Skin reddish-blue, flesh yellowish-green, medium firm, juicy. Stone averages 1.6g. Tree moderately hardy, medium vigor and bears fourth year in the orchard. 'Orija' equals in taste to 'Kirke's Plum,' but is more cold hardy.

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