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Fruit Varieties Journal 45(1):12-17 1991

Evaluation of Strawberry Cultivars with Different Degrees of Resistance to Red Stele[1]

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Abstract

Sixteen commercially grown strawberry cultivars with different degrees of resistance to red stele were evaluated for yield, plant characteristics and fruit quality. 'Bounty,' 'Midway,' and 'Sparkle' had sufficient interior and exterior fruit color, good to satisfactory flavor and are suitable for freezing. However, these cultivars as well as 'Redcoat' lacked sufficient fruit firmness. 'Bounty,' 'Redcoat,' 'Redchief' and 'Sparkle' had the highest yield in the three-year test. 'Annapolis,' 'Earliglow' and 'Scott' had reflexed calyx whereas 'Allstar,' 'Annapolis,' 'Cornwallis,' 'Earliglow,' 'Guardian' and 'Sunrise' were characterized by a raised neck suitable for mechanical dehulling. 'Sunrise' appeared to be the only cultivar free of leaf scorch and leaf spot. 'Tristar,' 'Redchief,' 'Lester,' 'Darrow' and 'Arking' roots had the lowest incidence of red stele when planted in a naturally-infested field. No relationship between fruit characteristics was observed (except for calyx and neck) which suggests the necessity to examine each individual trait.

by 'Kent' ('K68-58' x 'Raritan'), released in 1981 by Agriculture Canada Kentville (2).

Despite Quebec's predominant position as one of Canada's main strawberry-producing regions, no cultivars have been released in Quebec. However, a breeding program initiated by Agriculture Canada in 1982 was joined by Macdonald College of McGill University in 1987. The primary aim of this program is to develop high yielding, disease resistant cultivars for the processing as well as the fresh market (6).

The first step of this program was to identify the productivity of potential parents which had some degree of disease resistance, especially to red stele, and to evaluate these parents for processing and mechanical harvesting.

Materials and Methods

The study was conducted at L'Acadie, 35km south-east of Montreal, Quebec, 45° latitude and an elevation of 46m. The climate is characterized by extreme low temperatures (below -25°C) and irregular snow cover in winter, cool and humid springs, and hot, dry summers.

In 1986 and 1987, one-year old certified virus-free strawberry plants of 'Allstar,' 'Annapolis,' 'Arking,' 'Cornwallis,' 'Darrow,' 'Delite,' 'Earliglow,' 'Gilbert,' 'Guardian,' 'Lester,' 'Midway,' 'Redchief,' 'Redcoat,' 'Scott,' 'Sparkle,' 'Sunrise,' 'Surecrop,' 'Tristar' and 'Bounty' were planted on a clay loam soil with moderate drainage. Thirty plants of each cultivar were arranged in a completely randomized design with three replicates of 10 plants set 60 cm apart in the row (plot), with 120 cm between rows. The planting was done manually on a 10 cm raised bed and watered immediately with a high phosphorus starter solution. The planting was irrigated and pesticides were applied according to the recommendations of Conseil des Productions Végétales du Québec (1). All flowers were removed and runners kept and spaced within the 50 cm wide row. The plantation was mulched for winter protection in November of each year with 6-7 cm of straw. Seven harvests took place each year from mid June to late July. At harvesting, a representative 2 m section of each plot was selected and data for total yield and average fruit weight were collected. Each cultivar was assessed for percent juice loss after thawing by measuring the amount of juice released (ml). Ten fruits were used to rank the presence of a raised neck and reflexed calyx (Fig. 1), exterior and interior color (1 = pale, 5 = dark red), flavor (1 = unpleasant, 5 = good), fruit firmness (1 = soft, 5 = firm), plant vigor (1 = weak, 5 = vigorous), and resistance to foliage diseases (1 = infected, 5 = healthy), these being leaf scorch (*Diplocarpon earliana*, Ell. and Ev.) and leaf spot (*Mycosphaerella fragariae*, Tul.). Data for the 1987 and 1988 harvest (1986 planting) and the 1988 harvest (1987 planting) were combined and least square means were calculated over all three harvest years. All data except total yield and average fruit size were transformed using an arcsine transformation prior to performing the analysis of variance. An LSD multiple comparison, referred to as the 'probability of differences' (PDIFF), an option of General Linear Model of SAS (8) was applied to the least square means.

In 1986 the same culitvars were planted in a similar manner in a field which was naturally infested with *Phytophthora fragariae* at St-Gregoire, Quebec. Incidence of red stele was determined in June, 1987. Forty daughter plants per cultivar (10 plants per plot) were randomly selected and the percent of primary roots with visible reddening of the stele was determined for 5 roots per plant. The presence of the fungus was confirmed by microscopic examination of the five roots for observed sporangiophores after incubation of the roots in a solu-

tion of $MgCl_2$ and $CaCl_2$ (each 0.003 M) at 10 °C for seven days. The data were transformed using an arcsine transformation prior to performing the analysis of variance and an LSD multiple comparison, was applied to the least square means.

Results and Discussion

Total Yield and Average Fruit Size. Total yield and fruit size was averaged for all picking dates over the three harvest-years. All cultivars generally showed a decrease in fruit size as the picking season progressed. All cultivars had similar fruit size, 'Arking' and 'Allstar' which had significantly ($p < 0.05$) larger fruit, and 'Cornwallis' which had significantly smaller fruit (Table 1). 'Bounty,' 'Sparkle,' 'Redcoat' and 'Redchief' produced significantly higher yields compared to the rest. 'Allstar,' 'Annapolis' and 'Lester' were the least productive cultivars (Table 1). Standard error (SE) and coefficient of variation (CV) for the three years and two plantations in L'Acadie are presented in table 1. The SE and CV measure the amount of variation from harvest-year to harvest-year; the lower the value, the more stable are the cultivars. The most consistently high producers were 'Sparkle,' 'Redcoat' and 'Redchief,' which confirms the report of Hancock *et al.* (5). 'Midway' and 'Arking' were also consistant producers, but with lower yield. Among the cultivars tested, 'Bounty' produced the highest yield, but it was not a consistant cultivar during the three harvest-years.

Fruit Characteristics. Percent juice loss was measured after thawing to identify potential parents suitable for freezing and canning. 'Cornwallis' had the lowest ahd 'Delite' had the highest percent juice losses compared to the others. Out of the 19 cultivars tested, 'Allstar,' 'Arking,' 'Cornwallis,' 'Darrow,' 'Earliglow,' 'Guardian,' 'Redchief,' 'Redcoat,' 'Sunrise,' 'Surecrop,' 'Tristar' and 'Bounty' had less than 50% juice loss after thawing (Table 2).

Raised neck and reflexed calyx are the most important characteristics of strawberry cultivars for mechanical dehulling. Raised neck and reflexed

Table 1. Yield, average fruit size, standard error (SE) and coefficient of variation (CV) of 16 strawberry cultivars, planted in 1986 and 1987.†

Variety	Total yield (g $2m^{-1}$)			Average fruit size (g $berry^{-1}$)		
	Mean	SE	CV§	Mean	SE	CV§
Allstar	1609 c¶	239	42	10.3 ab	0.82	22
Annapolis	1601 c	451	69	6.1 cde	0.14	5
Arking	2522 bc	235	26	11.2 a	0.99	25
Bounty	4249 a	273	36	7.3 cd	0.32	24
Cornwallis	2513 bc	230	29	4.1 e	0.12	21
Darrow	2019 bc	333	41	7.4 cd	0.30	21
Delite	1848 bc	456	34	8.2 bcd	0.66	11
Earliglow	2188 bc	331	40	5.4 de	0.24	11
Gilbert	2899 bc	1252	61	7.6 bcd	0.93	17
Guardian	2908 bc	344	33	8.7 abc	0.87	28
Lester	1557 c	309	56	8.7 abc	0.43	14
Midway	2918 bc	190	24	6.4 cde	0.19	11
Redchief	3203 a	247	20	7.0 cde	0.18	6
Redcoat	3373 a	111	23	6.5 cde	0.26	27
Scott	2046 bc	525	36	6.6 cde	0.39	29
Sparkle	3468 a	205	23	6.3 cde	0.14	8

†Average of the three harvest-years (1987-1989).
§Coefficient of variability of three harvest-years.
¶Means with the same letter within the same column are not significantly different at 5% level of significance by LSD multiple comparison test.

Table 2. Ranking of 19 strawberry cultivars, for percent juice lost after thawing, neck size, position of sepals, exterior and interior color, fruit flavor, fruit firmness, plant vigor, and susceptibility to leaf diseases and *p. fragariae*.†

Variety	% Juice lost	Neck	Reflexed calyx	Color		Flavor	Fruit firmness	Plant vigor	Leaf diseases	Red stele§
				Ext.	Int.					
Allstar	46 bc¶	4.8 ab	3.9 bc	3.7 bc	3.0 c	3.0 bc	3.0 cd	4.2 b	--	8.4 bc
Annapolis	51 abc	4.0 bc	5.0 a	3.0 c	3.0 c	3.0 bc	3.3 c	3.7 c	4.0 b	19.8 bc
Arking	44 bcd	--	3.9 bc	--	--	3.0 bc	3.0 cd	--	--	3.1 c
Bounty	50 abc	3.2 cde	3.2 cde	4.5 a	3.0 c	4.0 a	3.0 cd	4.0 bc	3.7 b	79.2 a
Cornwallis	33 d	4.0 bc	4.0 bc	3.0 c	3.0 c	3.5 b	4.0 b	4.0 bc	4.0 b	17.7 bc
Darrow	46 bc	2.3 e	2.7 ef	3.7 bc	2.0 d	--	--	2.0 e	--	6.3 bc
Delite	60 a	--	3.7 bcd	2.0 d	2.0 d	--	--	--	--	9.4 bc
Earliglow	41 cd	5.0 a	5.0 a	4.0 ab	3.0 c	3.0 bc	--	4.0 bc	4.0 b	17.7 bc
Gilbert	55 ab	--	--	4.0 ab	2.3 d	2.3 de	--	--	--	9.4 bc
Guardian	46 bc	4.0 bc	--	2.0 d	3.0 c	3.0 bc	3.0 cd	4.0 bc	4.0 b	15.6 bc
Lester	53 abc	2.7 de	3.3 cde	3.3 bc	2.0 d	3.0 bc	3.0 cd	--	3.0 c	6.3 bc
Midway	53 ab	3.3 cd	2.3 f	4.0 ab	5.0 a	4.0 a	4.0 b	4.0 bc	3.0 c	13.4 bc
Redchief	42 cd	--	4.0 bc	3.0 c	3.0 c	3.0 bc	3.0 cd	3.0 d	3.0 c	5.0 bc
Redcoat	44 bc	3.8 c	3.0 def	3.0 c	2.0 d	2.8 cd	3.0 cd	3.0 d	4.0 b	31.5 bc
Scott	50 abc	2.3 e	4.3 ab	3.3 bc	3.0 c	1.7 f	3.3 c	4.0 bc	--	7.3 bc
Sparkle	54 ab	--	--	4.0 ab	3.0 c	4.0 a	2.5 d	4.0 bc	3.0 c	20.0 bc
Sunrise	46 bc	4.0 bc	3.7 bcd	3.0 c	2.0 d	--	5.0 a	5.0 a	5.0 a	19.8 bc
Surecrop	41 cd	3.7 c	3.7 bcd	3.0 c	2.3 d	3.0 bc	2.7 d	2.0 e	4.0 b	8.3 bc
Tristar	48 bc	2.7 e	3.7 bcd	3.0 c	3.7 b	2.0 ef	4.0 b	3.0 d	3.7 b	3.3 c

†Averaged over three harvest-years. An arcsine transformation was used prior to performing analysis of variance. See Figure 1 for neck size and arrangement of the calyx; exterior and interior color: 1 = pale, 5 = dark red; flavor: 1 = unpleasant, 5 = good; Fruit firmness: 1 = soft, 5 = firm; plant vigor: 1 = weak, 5 = vigorous; foliage disease: 1 = infected, 5 = healthy.

§Percent of roots infected by *P. fragariae*.

¶Means with the same letter within the same column are not significantly different at 5% level of significance by LSD multiple comparison test.

calyx minimize the cutting waste. 'Allstar' and 'Earliglow' had longer necks compared to the others, followed by 'Annapolis,' 'Cornwallis,' 'Guardian' and 'Sunrise.' 'Earliglow' and 'Annapolis' had the highest score for reflexed calyx. Among all the cultivars tested, only 'Annapolis,' 'Earliglow,' 'Cornwallis' and 'Allstar' had both raised necks and reflexed calyx (Table 2).

'Bounty,' 'Gilbert,' 'Earliglow,' 'Midway,' 'Sparkle,' 'Allstar' and 'Darrow' ranked highest for exterior color, whereas 'Guardian' and 'Delite' ranked lowest (Table 1). 'Cornwallis,' 'Midway,' 'Sparkle,' 'Bounty,' 'Tristar,' 'Guardian,' 'Scott,' 'Earliglow,' 'Redchief' and 'Annapolis' had attractive red flesh throughout.

Flavor is one of the most important single quality factors in processed food. Although the volatile flavors in strawberries have been identified (4), there has been little attempt to utilize the information for breeding selections which rate high in flavor. 'Sparkle,' 'Bounty' and 'Midway' ranked highest for flavor (Table 2), and could be used as parents to improve berry flavor (6). 'Tristar' and 'Scott' were the most undesirable ones in that respect (Table 1). 'Sunrise' had the firmest fruit followed by 'Midway,' 'Tristar' and 'Cornwallis.' 'Sparkle' fruit was the softest.

An attempt was made to find out if there was any relationship among different fruit characteristics. It seems that raised neck and reflexed calyx are positively correlated (Table 3) but this relation is not highly significant ($p = 0.08$). It has been reported that flavor is positively related to fruit color (8). Such correlations (r value) were not observed in our experiment (Table 3), indicating most of the fruit characteristics are independent of each other

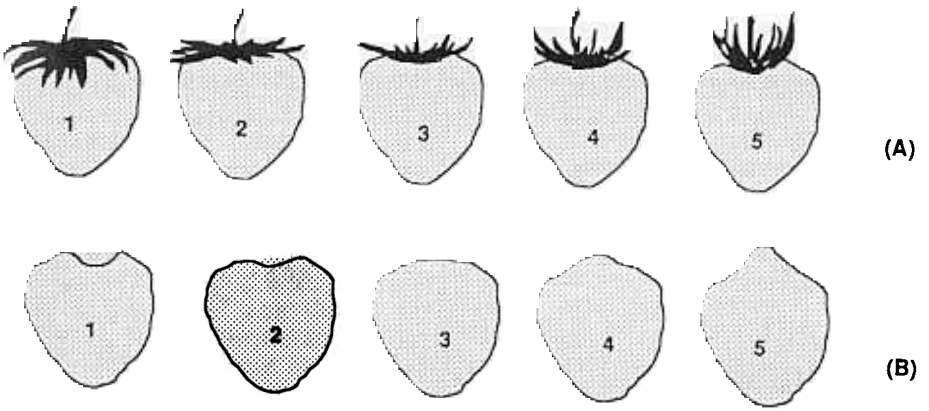

Figure 1. Classification of strawberry fruit with respect to their (A) calyx position and (B) shape of neck: 1 = poorest, 5 = most desirable.

and that examination of each individual fruit character is necessary to evaluate a cultivar.

Plant Characteristics. 'Sunrise' was the most vigorous cultivar and showed no symptoms of foliage diseases (leaf scorch and leaf spot). 'Allstar,' 'Earliglow,' 'Cornwallis,' 'Bounty,' 'Midway,' 'Guardian,' 'Sparkle' and 'Scott' were the next most vigorous cultivars, and 'Earliglow,' 'Annapolis,' 'Guardian,' 'Cornwallis,' 'Redcoat,' 'Bounty' and 'Tristar' showed the least amount of foliage diseases. 'Bounty' was the most susceptible cultivar to red stele and 'Arking' and 'Tristar' were the most resistant, although all the cultivars except 'Bounty' showed resistance.

Breeding Plan. The future plan of this breeding program is to use some of the above tested cultivars as parents to develop new genotypes. The selection will be based on suitability to mechanical harvesting and processing, winter hardiness, resistance to soil borne diseases (red stele and *verticelium* wilt), and herbicides. Other traits which will also be considered are as follows: concentrated ripening, elongated fruit neck, reflexed calyx, long erect peduncles and low juice loss after thawing. Based on the results to date 'Sparkle,' 'Midway,' 'Earliglow,' 'Surecrop' and 'Bounty' will be considered in future crosses.

Table 3. Pearson Correlation Coefficients (upper half matrix) and Prob > |R| (lower half matrix) for measured variables.†

	Mean ± SE Median	% Juice lost	Raised neck	Reflexed calyx	Color: Exterior	Color: Interior	Flavor	Fruit firmness
% Juice lost				-0.24	0.07	-0.00	-0.02	
Raised neck		0.10		0.49*	-0.06	0.02	0.33	
Reflexed calyx		0.34	0.08*		-0.23	-0.08	-0.41	
Exterior color		0.80	0.83	0.38		0.28	0.37	
Interior color		0.99	0.94	0.78	0.26		0.29	
Flavor		0.96	0.29	0.14	0.16	0.30		
Fruit firmness		0.61	0.99	0.70	0.65	0.53	0.64	

†An arcsine transformation was used prior to calculating Pearson correlation coefficients.
*Significant at 10% level.

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Fruit Varieties Journal 45(1):17-21 1991

Comparison of 'Cabernet Sauvignon' and 'Cabernet franc' Grapevine Dormant Bud Cold Hardiness

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Abstract

Cold hardiness of 'Cabernet Sauvignon' (CS) and 'Cabernet franc' (CF) dormant buds was compared during two winters by thermal analysis of bud freezing events. The vines were of the same age and planted in adjacent blocks of a northern Virginia vineyard. CF buds were typically one to two degrees (C) hardier than CS buds except in spring, when CF buds deacclimated more rapidly than CS buds. The general pattern of superior cold hardiness of CF buds is consistent with limited grower experience with whole-vine responses of these two *Vitis vinifera* cultivars to low temperature stress in the field.