American Pomological Society U. P. Hedrick Award for research paper by a student: (1983 First Place Award)

Spur Leaf Characteristics of Nine Apple Cultivars[1]

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Spur leaves are important in many aspects of fruit development. They are the first leaves to emerge from dormant buds of bearing apple trees, and comprise the majority of the tree canopy until shortly after bloom. Hansen (5) has indicated that the new leaves provide the "greater part by far" of photosynthates for the growth of fruit compared to carbohydrates mobilized from reserves. The removal of the spur leaves prior to or during bloom reduces fruit set (1). From a 3-year survey of more than 50 blocks of Delicious trees in major apple producing regions, Dennis (2) found that total solar radiation during the 3 week period prior to and during bloom correlated significantly with fruit set. Spur leaves comprise nearly the entire tree canopy during this critical period for fruit set and cell division and exert an important localized influence on fruit size, shape and calcium level that are important for quality and storage (3). A minimum spur leaf area is necessary for flower bud formation (6). Thus, many studies have indicated the vital role of spur leaves for fruit development, but the influence of various cultivars on spur leaves and other spur characteristics has not been well documented.

The present study was undertaken to evaluate the spur characteristics of 9 apple cultivars on M.7 rootstocks planted in 1964 at the Mahoning County Branch of OARDC near Canfield, Ohio. Trees were spaced 6.9 x 7.6 m, trained to a central leader and received standard cultural practices. Yield and growth from these trees has been previously reported (4). Twenty-six to 38 1-year-old spurs on 2-year-old limb sections were removed from each tree at pink bloom stage. Leaf area was measured by a Lambda portable area meter. Spur diameter was measured by a Mitutoyo Dial Caliper in the middle of the current bud scale scar. Live flowers were counted. All data was analyzed as a randomized complete block design with 5 single tree replicates. Coefficients of variation were calculated in order to compare variation of cultivars.

Idared had significantly more leaves per spur than other cultivars surveyed (Table 1). Generally, those cultivars having Jonathan parentage (Jonathan, Melrose, Idared), with the exception of Holiday, had more leaves per spur than Delicious or Golden Delicious types. The Delicious spur-type tree, Starkrimson, had significantly more leaves per spur and greater leaf number variation than the standard habit tree, Starking, but the trend was not evident for spur-type Sundale and standard Golden Delicious. Golden

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Delicious, Sundale and Mutsu had relatively consistent spur leaf numbers compared to all other cultivars as indicated by coefficient of variance.

Mutsu had the largest average spur leaf size followed by Melrose, Golden Delicious and Sundale. Leaves of Holiday were the smallest of all cultivars, only 28% the size of Mutsu leaves. The small leaf size of Jonathan was due in part to frost damage to abaxial leaf surface causing wrinkling and folding. Although some damage was observed on other cultivars, Jonathan was most severely affected. Generally, spur-type cultivars, Starkrimson and Sundale, had greater variation of spur leaf size than the respective standard-type cultivars, Starking and Golden Delicious.

Generally, cultivars with a large leaf area per spur produced the largest accumulated yields during a 17-year period (Table 1). When the cumulative yields of each cultivar were correlated with spur leaf area, the correlation coefficient was r = .65 and when Golden Delicious and Sundale were excluded due to their abnormal tree performance in this planting (4), the correlation coefficient was r = .93 A productivity rating ([yield x yield efficiency] ÷ yield variation) of all 9 cultivars was highly correlated to spur leaf area with a correlation coefficient of r = .87. Mutsu and Melrose had significantly greater spur leaf areas, and were vigorous and consistent producers. Holiday had significantly less area and greater leaf area variation within a tree than other cultivars and had low yield and yield efficiency with high yield variation. Golden Delicious was an efficient producer with low yield variation and likewise, had relatively large and consistent leaf area per spur.

Mutsu had the largest spur diameter and Holiday the smallest (Table 1). Although there was a 24% difference in spur diameters of these 2 varieties, both have consistent spur diameters within a tree as indicated by the coefficient of variation. Idared, Jonathan, and Starking spur diameter varied considerably within each tree.

Idared, Jonathan, and Holiday had significantly more flowers per spur than other cultivars studied (Table 1). Mutsu had only 2.4 flowers per spur, significantly less than other cultivars, probably due to early spring frost damage as indicated by brown and undeveloped flowers. In a previous report, Mutsu was one of the most susceptible cultivars to winter and spring frost injury (7). Golden Delicious, Sundale and Starking had reduced flower number per spur and greater variation of flower number compared to Idared, probably also due to frost injury. Likewise, Sundale and Delicious were rated as frost susceptible while Idared was most hardy.

Although there were differences between cultivars for each factor measured, significant tree-to-tree differences within a cultivar were also observed (Table 1). Spur diameter varied greatly between cultivars and all cultivars varied in spur diameter from tree-to-tree except Golden Delicious, Mutsu and Starkrimson, which were consistent between spurs and between trees. Idared and Jonathan were very consistent in number of flowers per spur. Sundale flower number varied greatly within a tree, but was consistent on all trees. Leaf number, area, and average leaf size variations were observed for trees of all cultivars. Although Holiday had the smallest average leaf size and greatest variation in average size, this cultivar was consistent tree-to-tree.

Spur diameter was generally significantly correlated to leaf number, spur leaf area and spur leaf size, although all correlations were low (Table 2). This suggests that spur size, inferring vascular connection, is only one of sev-

Table 1. Spur diameter, flower number, and leaf characters of 1-year-old spurs on 9 cultivars of 19-year-old trees.[z]

	Spur Leaves						Spur Diameter		Flowers		17-Year Accumulated Yield[x]		
Cultivar	No./ spur	Coef.[y] var.	Avg. Size (cm^2)	Coef. var.	Area (cm^2)	Coef. var.	(cm)	Coef. var.	No./ spur	Coef. var.	Lbs/ tree	Yield effic. lbs/cm^2	Yield coef. variation
Golden Delicious	6.4*d	.130	3.1*c	.198	19.9*b	.252	.337de	.011	4.3*c	.262	1130	9.7	55
Sundale	6.3*d	.105	3.4*bc	.244	21.4*b	.268	.370*bc	.010	4.3c	.297	1104	9.5	55
Mutsu	6.5*d	.114	4.7*a	.208	30.6*a	.235	.407a	.010	2.4*d	.419	2587	6.0	49
Starkrimson	7.1*c	.156	1.9*ef	.242	13.6*c	.308	.359cd	.011	5.0*b	.143	1274	7.6	63
Starking	6.4*d	.153	2.5*d	.219	15.9*c	.291	.358*cd	.012	4.5*c	.220	1890	5.7	72
Holiday	6.2*d	.140	1.3g	.278	8.5*d	.364	.309*e	.010	5.5*a	.176	1297	5.2	73
Melrose	7.8*b	.133	3.6*b	.191	27.9*a	.255	.389*ab	.010	5.0*b	.187	2165	7.2	59
Jonathan	7.5*bc	.148	1.7*fg	.241	13.2*c	.303	.336*de	.012	5.6a	.123	1689	6.7	49
Idared	9.7*a	.136	2.3*de	.244	22.1*b	.293	.396*ab	.013	5.7a	.121	2161	7.4	67
Avg		.135		.229		.285		.011		.216	1700	7.2	60

[z]All trees grown on M 7 rootstock. Mean separation within columns by LSD, 0.05 level.

[y]Estimate of coefficient of variation (spur-to-spur variation) derived by $\frac{\sqrt{MSE}}{\bar{x}}$, where $\bar{x}$ is variable mean, and MSE is error mean square term within tree.

[x]17 year accumulated yield data from Ferree, et al. 1982. Fruit Var. J. 36(2) 37-45.

*Significant tree-to-tree variation, [prob (f) <0.05].

Table 2. Correlation coefficients for spur diameter, flower number, leaf number, and leaf size of 9 cultivars of 19-year-old apple trees.[z]

	Correlation Coefficients (r-value)					
Cultivar	Spur dia. × Leaf no.	Spur dia. × Spur leaf area	Spur dia. × Leaf size	Spur dia. × Flower no.	Leaf no. × Flower no.	Leaf area × Flower no.
Golden Delicious	.41*	.55*	.46*	.27*	.29*	.21*
Sundale	.34*	.38*	.28*	.17*	.25*	.17*
Mutsu	.31*	.46*	.38*	−.03	.05	−.11
Starkrimson	.47*	.53*	.39*	.21	.17*	.07
Starking	.34*	.56*	.47*	.03	.26*	.03
Holiday	.29*	.44*	.43*	.10	.30*	−.16
Melrose	.40*	.52*	.44*	.18*	.21*	.09
Jonathan	.20*	.37*	.38*	.15	.36*	.35*
Idared	.15*	.37*	.38*	.23*	.25*	.17*

[z]All trees on M7 rootstock.

*$P(r) < 0.05$.

eral factors related to leaf development.

Flower number was significantly, but poorly, correlated to both spur diameter and leaf area of Golden Delicious, Sundale, and Idared, while a consistent relationship did not exist for other cultivars (Table 2). Flower and leaf number were significantly correlated for all cultivars evaluated except Mutsu due to the frost injury of Mutsu. However, because of the low level of these correlation coefficients, other factors must have prominent roles in determining flower and leaf number per spur.

In conclusion, previous reports indicate the importance of spur leaves to fruit development, and the present study has shown that there are differences between cultivars for spur diameter, flower number, leaf number, area, and size. Total spur leaf area or average leaf size appears to relate to tree productivity, efficiency and yield variation. Therefore, future observation of cultivars and breeding lines may be able to utilize these spur characteristics as a tool to predict tree performance and future productivity.

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