Fruit Quality of Pear Psylla-resistant Parental Germplasm

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Abstract. Sixteen interspecific backcross hybrid selections from various breeding programs have been selected as prospective parents for breeding for resistance of European-type pears to the pear psyllids (*Cacopsylla* spp.). The *Pyrus communis* × *P. pyrifolia* (n = 6) backcross selections are derived mostly from NJ 1, an open-pollinated *P. pyrifolia* seedling, and the *Pyrus communis* × *P. ussuriensis* (n = 9) backcross selections are derived from Illinois 76, an open-pollinated *P. ussuriensis* seedling, and one *Pyrus communis* × *P. ussuriensis* cultivar. Ratings of psylla resistance have been based primarily on multiyear orchard observations under no-pesticide and minimal pesticide conditions. To select the best prospective parents, data on fruit quality and tree traits were analyzed. Fruit characteristics included harvest date, fruit size and shape, skin color, percentage blush, russet, overall appearance, texture (flesh fineness), texture type, juiciness, overall grittiness and grit size, flavor acceptability and type, aroma, and a quality index, which was an unweighted total of the scores for appearance, texture, grit, flavor, and aroma. For this report, comparisons were made to ‘Bartlett’, the most widely grown U.S. pear cultivar. Both the *P. communis* × *P. pyrifolia* and *Pyrus communis* × *P. ussuriensis* backcross hybrid groups had significantly lower quality indices than ‘Bartlett’, and most individual traits were similar in this respect. There were significant differences among selections for all traits as were differences between years within genotype for most traits with some exceptions. Harvest date, percentage blush, appearance, juiciness, flavor, and the quality index were relatively stable from year to year. Flesh texture type varied within each group. The *P. communis* × *P. pyrifolia* selection NJ Rock R23 T252 had the highest quality index of the selections. For eight traits, various selections ranked higher than ‘Bartlett’, although the differences were not significantly higher with the exception of the russet score. Five selections appear to have sufficient quality and are being used as parents.

Host resistance to pear psyllids [*Cacopsylla pyri* (L.), *C. pyricola* (Förster), and *C. pyrisuga* (Förster)] is a major objective of several pear breeding programs in North America and Europe (Bellini and Nin, 2002; Brewer and Palmer, 2011; Lespinasse et al., 2008). Both adults and nymphs feed primarily in the vascular tissue of the leaves, petioles, and succulent shoots. Prolonged feeding in the phloem by nymphs affects the plant directly by inducing necrosis and premature defoliation. The nymphs excrete excess sugar as honeydew, which can cause russetting of young fruit. Sooty mold fungus grows on the honeydew, resulting in reduced photosynthesis and marked fruit. The insect is also the vector of the pear decline phyto-

plasma (Hibino et al., 1971). In North America, *C. pyricola* has rapidly developed resistance to commonly used pesticides, including organophosphates and pyrethroids, and biological controls are not always sufficiently effective. Resistant cultivars would reduce grower costs and enhance the sustainability of the pear industry.

The programs seek to combine resistance from *Pyrus ussuriensis* Maxim, *P. pyrifolia* (Burm.) Nakai, and from landraces of *P. communis* L. (Bell, 2013; Bell and Puterka, 2004; Braniste et al., 2008). The choice of parents for breeding must take into consideration the level of resistance to pear psylla and fruit quality and production traits. Germplasm with at least medium-sized fruit have been used in preference to the small-fruited Asian species (*P. betulifolia* Bunge, *P. calleryana* Decne., *P. fauriei* Schneid., and smaller-fruited *P. ussuriensis*) that are also resistant to pear psylla (Westigard et al., 1970). The fruit traits of many of the cultivars and selections used in breeding have not been well documented with the exception of *P. ussuriensis* × *P. communis* backcross selections from the Cornell University breeding program and the European landrace cultivars (Bell and van der Zwet, 1999). In general, the Cornell *P. ussuriensis* × *P. communis* selections are characterized by small to medium-sized

fruit (35 to 60 mm diameter), round to round-ovate and pyriform shape, moderate skin russetting, medium texture, coarse to moderately fine grit, and generally poor flavor with two exceptions (NY10353 and NY10354). The European landrace cultivars have larger fruit (54 to 70 mm in diameter), are more pyriform, and have less skin russet, but have generally coarse, firm texture, elevated levels of grit, and insipid to poor flavor.

Several advanced generation interspecific *Pyrus communis* × *P. pyrifolia* and *Pyrus communis* × *P. ussuriensis* backcross selections are also being used in our breeding program as sources of resistance to pear psylla. The degree of resistance to nymphal feeding of most of these selections has been characterized (Bell, 2013). The purpose of this study was to document and rank this germplasm for fruit quality traits as an aid to selecting appropriate parents for breeding.

Materials and Methods

Sixteen interspecific backcross hybrid breeding selections from the pear breeding programs of Purdue University, Rutgers University, the University of Illinois, and Cornell University were evaluated for fruit quality traits. The selections were chosen based on the degree of resistance to pear psylla estimated from laboratory assays of nymphal feeding resistance (Bell, 2013; Bell and van der Zwet, 1999) for NJ A2 R21 T89, NJ A2 R27 T97, NJ B9 R1 T117, NJ Rock R25 T238, NJ 11, Purdue 77-73, and ‘Summercrisp’ and/or orchard observations and nymph counts (all other selections; unpublished data). The *P. communis* × *P. pyrifolia* selections (n = 6) were derived mostly from NJ1, an open-pollinated *P. pyrifolia* seedling, and the *P. communis* × *P. ussuriensis* selections (n = 10) were mostly derived from Illinois 76, an open-pollinated *P. ussuriensis* seedling. NY 10369 was derived from Illinois 65, an open-pollinated seedling of *P. ussuriensis*, and ‘Summercrisp’ was derived from an unknown *P. ussuriensis* parent. Comparisons were made to ‘Bartlett’, the most widely grown U.S. pear cultivar. Fruit were harvested when judged to be mature on the basis of ground color and darkening seedcoats. Samples of five to six fruit harvested were put into perforated polyethylene bags and stored at –1 °C in a common air cold room for 4 to 12 weeks. In some years and for 11 selections, two to six harvests ≈1 week apart were made. The number of years of data varied from 1 (for four selections) to 9. ‘Bartlett’ was sampled for 14 years. Fruit characteristics included harvest date, fruit size and shape, skin color, percentage blush, russet, overall appearance, texture (flesh fineness), texture type, juiciness, overall grittiness and grit size, flavor acceptability and type, aroma, and a quality index, which was an unweighted total of the scores for appearance, texture, grit, flavor, and aroma. Diameter was measured in millimeters. Scores for russet, appearance, texture, juice, grit, and flavor were based on a scale in which 1 = very poor and 9 = excellent. Aroma was scored with 0 = no aroma

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Table 1. Mean fruit quality by species pedigree.

Species pedigree	No. of selections	Trait ^c								
		Diam ^a	Russet	Appear	Texture	Juice	Grit	Flavor	Aroma	Quality index ^b
<i>communis</i> (Bartlett)	1	66.8 a ^x	6.9 a	6.9 a	6.6 a	6.3 a	6.3 a	6.6 a	1.6 a	34.7 a
<i>communis</i> × <i>pyrifolia</i>	6	66.4 a	5.6 b	5.9 b	5.2 b	5.3 b	5.3 b	5.0 b	0.9 b	28.7 b
<i>communis</i> × <i>ussuriensis</i>	10	60.4 b	5.9 b	5.9 b	5.6 b	5.4 b	5.4 b	4.3 b	0.5 c	27.5 b

^aDiameter was measured in millimeters. Scores for russet, appearance, texture, juice, grit and flavor were based on a scale in which 1 = very poor and 9 = excellent. Aroma was scored with 0 = no aroma and 3 = intense aroma.

^bQuality index = unweighted sum of scores for appearance, texture, juiciness, grit, flavor and aroma (maximum = 48).

^cMeans followed by the same letter are not significantly different at the $P = 0.05$ level.

Table 2. Fruit quality traits of pear psylla-resistant parents and 'Bartlett'.

Cultivar/selection	Species pedigree ^c	Trait ^b									Texture type ^w
		Diam ^y	Russet	Appear	Texture	Juice	Grit	Flavor	Aroma	Quality index ^x	
Bartlett	<i>com</i>	66.8 ab ^v	6.9 bcd	6.9 a	6.6 a	6.3 ab	6.8 ab	6.6 a	1.6 a	34.7 a	Me
NJ Rock R23 T252	<i>com</i> × <i>pyr</i>	68.6 a	6.7 bc	6.8 ab	6.2 ab	6.5 a	6.6 abc	6.3 ab	0.6 bcd	33.3 a	Me
NY 1-21-22	<i>com</i> × <i>uss</i>	57.3 bc	8.2 a	6.2 a-d	7.0 a	6.3 abc	7.2 ab	5.7 abc	1.0 abc	33.2 ab	Me
NJ A2 R27 T97	<i>com</i> × <i>pyr</i>	66.0 ab	7.5 abc	7.3 abc	6.5 a-d	5.0 abc	7.8 a	6.0 abc	0.0 d	32.5 abc	Me
NJ B9 R1 T117	<i>com</i> × <i>uss</i>	57.6 b	7.2 a-d	7.2 ab	6.0 abc	4.8 abc	6.7 abc	4.9 abc	1.1 abc	30.6 abc	Me
NJ A2 R21T89	<i>com</i> × <i>uss</i>	56.0 ab	8.0 ab	5.0 cd	7.0 ab	6.5 abc	6.5 a-d	5.0 abc	0.5 a-d	30.5 abc	Cr
NJ A2 R70 T179	<i>com</i> × <i>pyr</i>	32.1 ab	7.4 a-d	6.4 a-d	4.6 bcd	6.2 abc	4.4 ef	5.8 abc	1.3 abc	28.8 abc	Me
NJ 11	<i>com</i> × <i>pyr</i>	68.9 a	1.1 i	4.9 cd	4.4 d	5.3 abc	4.5 e	4.3 bc	1.3 ab	27.2 bc	Cr
NY 10369	<i>com</i> × <i>uss</i>	58.0 ab	4.0 e-h	4.0 a-d	6.0 a-d	7.0 abc	5.0 b-e	4.0 abc	1.0 a-d	27.0 abc	Me
Indiana TH 1-187	<i>com</i> × <i>uss</i>	61.3 ab	6.3 b-f	5.1 a-d	5.0 a-d	5.1 abc	5.7 b-e	4.3 abc	1.8 a	27.0 bc	Cr
NJ Rock R25 T238	<i>com</i> × <i>uss</i>	56.5 bc	5.8 cde	6.2 a-d	4.8 bcd	5.5 abc	5.3 cde	4.5 abc	0.5 bcd	26.8 bc	Me
Illinois IP-93	<i>com</i> × <i>pyr</i>	68.8 a	5.8 c-f	5.6 bcd	5.1 bcd	4.2 c	5.5 def	4.1 c	1.2 ab	25.9 c	Cr
NJ A2 R58 T260	<i>com</i> × <i>uss</i>	68.5 ab	7.0 abc	6.0 a-d	5.0 a-d	5.5 abc	6.5 a-d	3.0 bc	0.0 d	25.5 bc	Cr
Summercrisp	<i>com</i> × <i>uss</i>	72.5 a	7.0 abc	8.0 abc	5.5 a-d	3.0 abc	5.0 b-e	4.5 abc	0.0 d	25.0 abc	Me
NJ A2 R59 T69	<i>com</i> × <i>uss</i>	63.8 ab	1.8 hi	6.4 a-d	4.5 cd	5.1 abc	5.0 de	3.8 bc	0.0 d	24.8 c	Cr
Illinois 5E-18	<i>com</i> × <i>pyr</i>	6.9 ab	4.8 efg	4.4 d	4.6 cd	4.4 bc	5.1 de	3.2 c	1.3 ab	24.6 c	Cr
Purdue 77-73	<i>com</i> × <i>uss</i>	52.5 b	3.7 g	5.0 a-d	5.3 a-d	5.0 abc	4.8 de	3.8 abc	1.0 a-d	24.3 c	Cr
Significance of differences ^u											
Selection		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	—
Year (selection)		0.0004	0.0015	0.0988	0.0007	0.5524	0.0010	0.8767	<0.0001	0.4616	—

^aSpecies pedigree abbreviations: *com* = *P. communis*; *pyr* = *P. pyrifolia*; *uss* = *P. ussuriensis*.

^bDiameter was measured in millimeters. Scores for russet, appearance, texture, juice, grit, and flavor were based on a scale in which 1 = very poor and 9 = excellent. Aroma was scored with 0 = no aroma and 3 = intense aroma.

^cQuality index = unweighted sum of scores for appearance, texture, juiciness, grit, flavor, and aroma (maximum = 48).

^wTexture type: Me = melting or buttery; Cr = crisp.

^uMeans in a column followed by the same letter are not significantly different at the $P = 0.05$ level.

^vSignificance of differences was determined by an F-test for fixed effects and a Z-test for random effects by SAS PROC MIXED (Littell et al., 1996; SAS Institute, Inc., 2010).

and 3 = intense aroma. The quality index was computed as the unweighted sum of scores for appearance, texture, juiciness, grit, flavor, and aroma (maximum = 48). For texture type, Me = melting or buttery and Cr = crisp.

The data were analyzed according to a mixed model nested design in which selections were treated as fixed effects and year and harvest samples within year were considered random effects. The analysis was performed using SAS PROC MIXED (Littell et al., 1996; SAS Institute, Inc., 2010). Least-squares means and ses were computed. Mean separation for this procedure was performed using the Tukey-Kramer honestly significant difference method. The Bonferroni option was used to adjust for multiple comparisons. Mean separation letters for main effects were assigned by the SAS macro PDMIX 800 (Saxton, 1998).

Results and Discussion

Both *P. communis* × *P. pyrifolia* and *P. communis* × *P. ussuriensis* scored lower than the 'Bartlett' control for all fruit quality traits

and the seven-trait quality index, except fruit diameter, for which the species pedigree group mean for *P. communis* × *P. pyrifolia* selections was similar to 'Bartlett' and better than *P. communis* × *P. ussuriensis* (Table 1). There were significant differences among 'Bartlett' and the psylla-resistant selections for all traits (Table 2). Differences between years were non-significant for appearance, juiciness, flavor, and the quality index, but significant for the fruit diameter, russet, texture, grit, and aroma. 'Summercrisp', NJ (New Jersey) 11, Illinois IP-93, and NJ Rock R23 T252 had the largest fruits. NY (New York) 1-21-22 and NJ A2 R21 T89 had the least russet, mostly just from prominent lenticles. NJ 11 and NJ A2 R59 T69 are almost entirely russeted, similar to some *P. pyrifolia* cultivars. 'Summercrisp' was scored highest for mean overall appearance, although several other selections were not statistically different and similar to 'Bartlett', the commercial control cultivar. NJ B9 R1 T117 is interesting in that as the fruit matures, the skin turns from completely red to an attractive blushed fruit. Flesh texture varied from moderately coarse

(scores less than 5) to finely grained (6 or higher) with NY 1-21-22, NJ A2 R21 T89, Bartlett, and NJ A2 R27 T97 scoring the highest. The juiciest fruits were those of NY 10369, NJ A2 R21 T89, and NJ Rock R23 T252. The least and smallest grit content were fruits of NJ A2 R27 T97 and NY 1-21-22, both melting flesh types. In general, the crisp or non-melting flesh selections tended to have lower grit scores. 'Bartlett' had the highest flavor score, indicative of the importance of more balanced and aromatic flavor to that trait. The mean scores of NJ Rock R23 T252 and NJ A2 R27 T97 were greater than 6.0, the minimally acceptable score for a commercial cultivar. A score of 6 means that the fruit is sweet with at least a trace of acidity and typical pear flavor. The highest mean aroma scores were those of 'Bartlett' and the *P. communis* × *P. ussuriensis* hybrid, IND TH 1-187, which tends to have the "winey" flavor and elevated acidity of some *P. ussuriensis* cultivars. 'Bartlett' had the highest quality index, but five selections from both interspecific pedigree groups also had mean scores greater than 30.

The texture type varied within each interspecific pedigree group. Within the *P. communis* × *P. pyrifolia* group, three selections were classified as having crisp or non-melting flesh; however, with the exception of NJ 11, the texture was not as finely grained as that typical of pure *P. pyrifolia* cultivars. The other tree selections were classified as having melting flesh, that is, flesh that softens. Typically, the texture of these selections was a bit firmer than and coarser than pure *P. communis* cultivars. Within the *P. communis* × *P. ussuriensis* group, five of the 10 selections had crisp, or non-melting, flesh. Typically, pure *P. ussuriensis* tends to have softening flesh. Therefore, the Illinois 76 ancestor (also referred to as *Pyrus ussuriensis* 76) is probably an interspecific hybrid with *P. pyrifolia*.

There was considerable variability in the fruit quality traits of the *P. communis* × *P. pyrifolia* and *P. communis* × *P. ussuriensis* interspecific hybrid selections. Those scoring

highest for individual traits and the quality index were NJ Rock R23 T252, NY 1-21-22, NJ A2 R27 T97, NJ B9 R1 T117, and NJ A2 R21 T89. These selections can be recommended for use in breeding programs for the development of pear psylla-resistant pear cultivars.

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