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# OH × F Paternity Perplexes Pear Producers

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## Abstract

Early in the 20th century, a collection of fire blight resistant pears from around the world was assembled in southern Oregon in an effort to develop improved rootstocks. 'Old Home' and 'Farmingdale' are two cultivars from Illinois that exhibited strong fire blight resistance and useful horticultural traits. Both became important as interstem stocks and as parents in the development of new rootstocks. In the 1950s, an Oregon nurseryman collected seed from an 'Old Home' tree in British Columbia purportedly pollinated by 'Farmingdale' and hundreds of numbered selections of this cross of 'Old Home' × 'Farmingdale' (OH×F) were evaluated. Several OH×F selections are now valued as rootstocks worldwide, and 45 unique OH×F selections are maintained at the USDA-ARS National Clonal Germplasm Repository (NCGR), in Corvallis, Oregon. Simple Sequence Repeat (SSR) or microsatellite-based profiles were generated for 'Old Home', 'Farmingdale', 8 OH×F selections, and several reference pear cultivars at NCGR using a standard fingerprinting set developed by the European Cooperative Programme for Plant Genetic Resources. 'Farmingdale' is thought to be a seedling of 'Beurré d'Anjou'. Our study showed that 'Farmingdale' shared at least one SSR allele with 'Anjou' at each locus tested, confirming this parental relationship. Our studies showed that all OH×F selections shared an allele with 'Old Home' at each locus, with one allele carrying a suspected pair of base deletions. However, based on our SSR results, it is impossible for 'Farmingdale' to be the pollen parent for any of the OH×F selections examined. Evaluation of the world pear collection at NCGR with this fingerprinting set established the cultivar 'Bartlett' as the actual pollen parent of these rootstock clones. Fruit and leaf morphology is also consistent with 'Bartlett' and not 'Farmingdale' as a parent of OH×F rootstock selections. The highly fire blight resistant 'Farmingdale' is apparently very under-represented in the pedigrees of current pear rootstocks, and deserves renewed consideration.


Early in the 20th century, Oregon State University (OSU) professor Frank Reimer began scouring the world for *Pyrus* germplasm with resistance to the important bacterial disease fire blight (*Erwinia amylovora* (Burrill) Winslow et al.), which made its first appearance in the Rogue River Valley in 1906 (Reimer, 1925). Reimer was the first superintendent of the OSU Southern Oregon Experiment Station near Medford. From 1917 to 1919 his travels took him to China, Korea, Manchuria, and Japan where he collected scions from many local pear cultivars and seed from pear wild relative species (Reimer, 1919; Fig. 1). He also collected seed from wild and hedgerow perry pears in France, and clones of hundreds of the leading pear cultivars of Western Europe and North America. Seedling populations were generated and clones were grafted and established at the OSU station in Talent, Oregon, where the diverse germplasm collections were evaluated for fruit quality, disease resistance and as potential rootstocks (Reimer, 1919; Reimer, 1925;

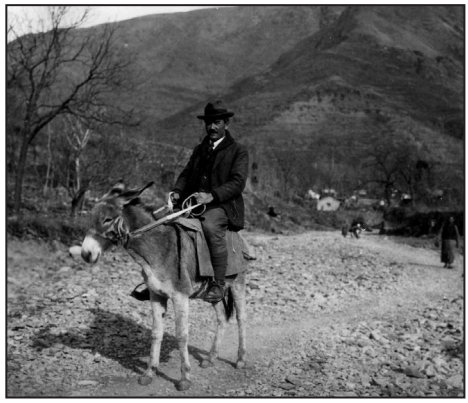

**Fig. 1.** Frank C. Reimer traveling while investigating pears in northern China in 1919.

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Hartmann, 1957). Two of Professor Reimer's most valuable discoveries came from a 1915 trip to visit fruit grower Benjamin Buckman in Farmingdale, Illinois. One was the cultivar 'Farmingdale', an open pollinated seedling Buckman had found near a 'Beurré d'Anjou' tree on his farm, and the other was 'Old Home', a seedling that had come from a nursery in Paris, Illinois some years earlier. Reimer observed both of these trees to be completely free of fire blight and he brought scions from 'Old Home' back to Oregon when he returned. 'Farmingdale' scions were sent to him several years later (Hummer, 1998; Westwood and Brooks, 1963; Westwood, 1967). After more than a decade of observing natural infections, and performing artificial inoculations in southern Oregon with *E. amylovora*, Reimer found many pear species selections and Asian cultivars with strong fire blight resistance, but only three European cultivars: 'Farmingdale', 'Longworth', and 'Old Home' had excellent blight resistance as trunk stocks (Reimer, 1925). The many valuable pear selections identified or developed by Reimer and his successors were later transferred to the National Clonal Germplasm Repository at Corvallis, Oregon when the USDA Agricultural Research Service established this genebank in 1981 (Postman et al., 2006; Westwood, 1982).

*'Farmingdale'.* The origin and characteristics of 'Farmingdale' are discussed in considerable detail by Reimer (Reimer, 1925; Reimer, 1950). It is apparently a pure form of *P. communis* which originated as a chance seedling in the orchard of Benjamin Buckman, at Farmingdale, Illinois. The fruit size is medium to large, and it resembles 'Anjou' in form and coloration. Flesh is white, fairly fine, buttery, moderately juicy, and quite free of grit. It is reasonably sweet but somewhat lacking in desirable flavor characteristics, and ripens in midseason. The original seedling was discovered close to an 'Anjou' tree, which was presumed to be the parent. Hartmann (1957) noted "while this pear is of little value for its fruit, it is quite remarkable in other characteristics. Its tree is vigorous, well formed, fairly productive, and is the most blight resistant of all the *P. communis* cultivars tested at the Southern Oregon Branch Experiment Station."

*'Old Home'.* 'Old Home' is also apparently a pure form of *P. communis* that originated as a chance seedling with B.O. Curtiss, at Paris, Illinois (Hartmann, 1957) and was growing in Benjamin Buckman's trial orchard in Farmingdale prior to 1907 (Ragan, 1908). The fruit of 'Old Home' is small, round, slightly truncate, with no neck. Skin is yellow-green, becoming yellow when ripe. Flesh is white to yellow, fine textured, becoming soft and tender when ripe with few stone cells, medium dry, subacid and with poor flavor (Howlett, 1957). While its fruit is of no consequence, the variety was widely used as a blight resistant trunk and framework stock, and as a very good source of blight resistant seedlings. When crossed with 'Farmingdale', a high percentage of the seedlings were very blight resistant as well as vigorous and uniform in growth (Hartmann, 1957). Reimer (1925) found 'Old Home' to have very good graft compatibility with quince and it has since been used as an interstem bridge for incompatible pear cultivars. Westwood (1967) showed that 'Old Home' is also graft compatible on hawthorn (*Crataegus sp*.) rootstock. When the disease Pear Decline spread through the pear growing areas of British Columbia in the 1940s and through Washington, Oregon and California in the 1950s and 1960s, it was found that trees with 'Old Home' root or trunk stocks were much more resistant to pear decline as well as to fire blight. 'Old Home' was extremely difficult to propagate as a clonal rootstock, however, while many OH×F selections rooted much easier from hardwood cuttings (Westwood and Brooks, 1963).

*'Old Home' and 'Farmingdale' in breeding.* In the mid 1920s, following the death of Benjamin Buckman, the original 'Farmingdale' and 'Old Home' trees in Illinois were destroyed, and the trees established at South-

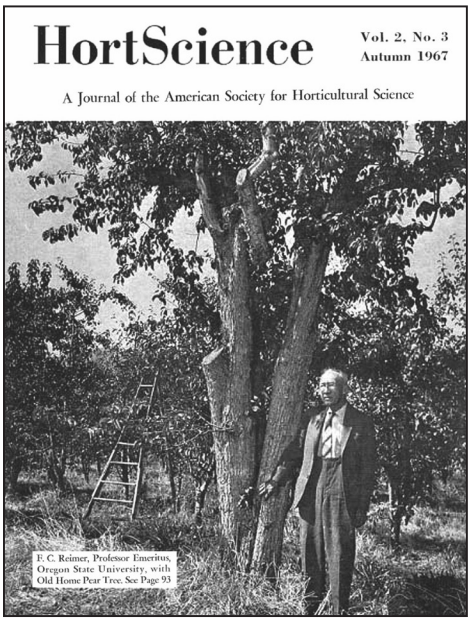


**Fig. 2.** HortScience cover in 1967 showing F. Reimer by original Old Home tree recently transplanted to Talent, Oregon.

ern Oregon Experiment Station became the primary source of nursery stock (Fig. 2; Brooks, 1984; Hummer, 1998; Westwood, 1967). Reimer (1950) found in the 1930s that when 'Farmingdale' was used as a pollen parent in crosses with other blight resistant selections, a high percentage of the resulting seedlings exhibited a high resistance to blight. This was especially true when 'Old Home' was the seed parent. Although a number of crosses between other blight resistant parents resulted in >90% seedlings that were resistant to blight following inoculation, many of those resistant seedlings became infected when a susceptible cultivar such as 'Bartlett' or 'Beurré Bosc' was grafted onto them. In those cases, fire blight could spread from an infected cultivar across the graft union into the rootstock. However, the OH×F seedlings were resistant even to the spread of fire blight from infection of a grafted cultivar (Reimer, 1950). Based on Reimer's work, 'Old Home' and 'Farmingdale' became important parent stocks for the development of both rootstock and edible pear cultivars. Several important Canadian cultivars obtained their fire blight resistance from 'Old Home', and at least two US fruit cultivars have 'Farmingdale' in their pedigrees (Table 1). By far, the most important use of 'Farmingdale' and especially 'Old Home' has been in the development of pear rootstocks. 'Old Home' in particular has been a valuable parent in rootstock breeding programs in France, UK, Germany, and elsewhere (Table 1; Elkins et al., 2012).

*OH×F selections.* One of Reimer's goals was to establish a mother block of 'Old Home' and 'Farmingdale' at the Southern Oregon Experiment Station to generate seed for producing blight resistant seedling rootstocks. Oregon nurseryman Lyle Brooks was concerned about the variability of pear cultivars grafted onto OH×F seedling rootstocks, and he set out to develop clonal rootstocks from this cross. In 1952, he obtained half a kilogram of seed from an isolated block of 'Old Home' trees planted with 'Farmingdale' pollenizers at the Canada Research Station in Summerland, British Columbia. Of the thousands of resulting seedlings, he planted 516 in a nursery block and evaluated them for ease of propagation from cuttings and other traits (Brooks, 1984; Westwood and Brooks, 1963). Propagation by hardwood cuttings was successful, and thirteen of the more easily propagated OH×F numbered selections (OH×F 18, 34, 51, 69, 87, 97, 112, 198, 217, 230, 267, 333, and 361) were extensively evaluated at OSU for disease and insect resistance, environmental tolerance, anchorage, dwarfing and fruit production of grafted cultivars (Lombard and Westwood,1987). More than 40 OH×F selections, including the 13 above, are preserved at the USDA genebank in Corvallis (Table 2). Some continue to be propagated worldwide and are in high demand for new plantings even though they lack the size control and precocity demanded for high density orchards (Elkins et al., 2012). OH×F 333 was selected for its resistance to multiple diseases and moderate size control

**Table 1.** Pear selections reported to have either 'Old Home' or 'Farmingdale' in the pedigree, and USDA genebank accession numbers.

| Plant name | Pedigree | Accession no. | Origin |
|---|---|---|---|
| Farmingdale in Pedigree | | | |
| P. betulifolia-2 x Farmingdale | P. betulifolia-2 x Farmingdale | PI 541785 | United States |
| Rogue Red | Comice x (Seckel x Farmingdale sdlg. 122) | PI 541252 | United States |
| Vistica Nectar | Farmingdale x Burkett | none | United States |
| Old Home in Pedigree | | | |
| AC Harrow Gold (HW 616) | Harvest Queen x Harrow Delight | none | Canada |
| BU 2/33 (Pyro II) | Old Home x Bonne Louise d'Avranches | PI 617679 | Germany |
| Harrow Delight (HW 603) | Bartlett x (Early Sweet x Old Home) | PI 541431 | Canada |
| Harrow Sweet (HW 609) | Bartlett x (Old Home x Early Sweet) | PI 617562 | Canada |
| Harrow selection HW 623 | Harrow Sweet (Old Home x Early Sweet) x HW 605 | none | Canada |
| Harrow selection HW 624 | Harrow Sweet x NY10353 | none | Canada |
| Nijisseiki x Old Home | Nijisseiki x Old Home | PI 541767 | United States |
| OH 11 (Pyriam) | Seedling of Old Home | CPYR 2700 | France |
| OH 20 fire blight resistant rootstock | Old Home seedling selection | PI 541237 | United States |
| OH 50 fire blight resistant rootstock | Old Home seedling selection | PI 541238 | United States |
| Old Home x P. betulifolia-1 | Old Home x P. betulifolia-1 | PI 541787 | United States |
| Old Home x P. betulifolia-1 | Old Home x P. betulifolia-1 | PI 541788 | United States |
| Pyrodwarf | Old Home x Bonne Louise d' Avranches | PI 617654 | Germany |
| QR 708-02 | BP-1 x Old Home | PI 617680 | United Kingdom |
| QR 708-12 | BP-1 x Old Home | CPYR 2704 | United Kingdom |
| QR 708-36 | BP-1 x Old Home | CPYR 2705 | United Kingdom |
| Nijisseiki x Old Home (seedlot) | Nijisseiki x Old Home W-6 | PI 541753 | United States |
| Old Home x Bartlett (seedlot) | Old Home x Bartlett | PI 541380 | United States |

to be the standard clonal rootstock for the thousands of pear clones maintained at the USDA genebank (Postman, 2008a; 2008b). A new generation of seedlings generated from open pollinated (OP) seed collected from an isolated group of select OH×F clones (OH×F 40, 51, 87, 333 and 339) resulted in the Horner rootstock series (Table 2; Mielke and Smith, 2002; Mielke and Sugar, 2004). Horner 4 is under evaluation in the 2005 NC-140 collaborative pear rootstock trial (Elkins et al., 2011), and a trial comparing Horner 4, Horner 10 and OH×F 87 was established in 2009 in the states of Oregon and Washington (Einhorn, personal communication).

*DNA fingerprints*. Bassil and Postman (2009) developed expressed sequence tag (EST)-simple sequence repeat (SSR) markers and evaluated them for usefulness in a diverse collection of individuals from the three most commonly cultivated pear species: *P. communis*, *P. pyrifolia* and *P. ussuriensis* at the USDA genebank. They found that 'Farmingdale' shared one SSR allele with 'Anjou' at each of 10 loci, suggesting that 'Anjou' was very likely the maternal parent of 'Farmingdale', as Buckman and Reimer had suspected nearly a century earlier (Bassil and Postman, 2009; Hartmann, 1957; Reimer, 1925). OH×F 333 was the only selection included in that study and appeared to share one allele with either 'Old Home' or 'Farmingdale', thus confirming its reported parentage. This paper reports on the pheno-

**Table 2.** Pear selections reported to have both 'Old Home' and 'Farmingdale' in pedigree, and USDA genebank accession numbers.

| Plant name | Pedigree | Accession no. | Origin |
|---|---|---|---|
| Harrow selection HW 621 | (Anjou x Farmingdale) x Harrow Delight | none | Canada |
| Horner 4 | O.P. from population of OHxF 40, 51, 87, 333 & 339 | CPYR 2955 | United States |
| Horner 10 | O.P. from population of OHxF 40, 51, 87, 333 & 339 | CPYR 2956 | United States |
| Horner 51 | O.P. from population of OHxF 40, 51, 87, 333 & 339 | PI 657931 | United States |
| OHxF 1 | Old Home x Farmingdale seedling selection | PI 541408 | United States |
| OHxF 2 | Old Home x Farmingdale seedling selection | PI 541413 | United States |
| OHxF 4 | Old Home x Farmingdale seedling selection | PI 541409 | United States |
| OHxF 5 | Old Home x Farmingdale seedling selection | PI 541410 | United States |
| OHxF 7 | Old Home x Farmingdale seedling selection | PI 541399 | United States |
| OHxF 9 | Old Home x Farmingdale seedling selection | PI 541421 | United States |
| OHxF 18 | Old Home x Farmingdale seedling selection | PI 541397 | United States |
| OHxF 23 | Old Home x Farmingdale seedling selection | PI 541411 | United States |
| OHxF 29 | Old Home x Farmingdale seedling selection | PI 541398 | United States |
| OHxF 34 | Old Home x Farmingdale seedling selection | PI 541412 | United States |
| OHxF 40 | Old Home x Farmingdale seedling selection | PI 541402 | United States |
| OHxF 51 | Old Home x Farmingdale seedling selection | PI 541369 | United States |
| OHxF 58 | Old Home x Farmingdale seedling selection | PI 541454 | United States |
| OHxF 69 | Old Home x Farmingdale seedling selection | PI 665738 | United States |
| OHxF 87 | Old Home x Farmingdale seedling selection | PI 541415 | United States |
| OHxF 97 | Old Home x Farmingdale seedling selection | PI 541370 | United States |
| OHxF 101 | Old Home x Farmingdale seedling selection | PI 541416 | United States |
| OHxF 109 | Old Home x Farmingdale seedling selection | PI 541417 | United States |
| OHxF 112 | Old Home x Farmingdale seedling selection | PI 541418 | United States |
| OHxF 130 | Old Home x Farmingdale seedling selection | PI 541406 | United States |
| OHxF 132 | Old Home x Farmingdale seedling selection | PI 541404 | United States |
| OHxF 198 | Old Home x Farmingdale seedling selection | PI 541419 | United States |
| OHxF 217 | Old Home x Farmingdale seedling selection | PI 541371 | United States |
| OHxF 226 | Old Home x Farmingdale seedling selection | PI 541372 | United States |
| OHxF 230 | Old Home x Farmingdale seedling selection | PI 541420 | United States |
| OHxF 247 | Old Home x Farmingdale seedling selection | PI 541422 | United States |
| OHxF 257 | Old Home x Farmingdale seedling selection | PI 541396 | United States |
| OHxF 259 | Old Home x Farmingdale seedling selection | PI 541423 | United States |
| OHxF 261 | Old Home x Farmingdale seedling selection | PI 541401 | United States |
| OHxF 266 | Old Home x Farmingdale seedling selection | PI 541424 | United States |
| OHxF 267 | Old Home x Farmingdale seedling selection | PI 541400 | United States |
| OHxF 280 | Old Home x Farmingdale seedling selection | PI 541425 | United States |
| OHxF 282 | Old Home x Farmingdale seedling selection | PI 541426 | United States |
| OHxF 288 | Old Home x Farmingdale seedling selection | PI 541373 | United States |
| OHxF 319 | Old Home x Farmingdale seedling selection | PI 541427 | United States |
| OHxF 333 | Old Home x Farmingdale seedling selection | PI 541405 | United States |
| OHxF 340 | Old Home x Farmingdale seedling selection | PI 541403 | United States |
| OHxF 361 | Old Home x Farmingdale seedling selection | PI 541374 | United States |
| OHxF 377 | Old Home x Farmingdale seedling selection | PI 541428 | United States |
| OHxF 501 | Old Home x Farmingdale seedling selection | PI 541407 | United States |
| OHxF 512 | Old Home x Farmingdale seedling selection | PI 541414 | United States |
| OPR-005 OHxF C-44 | Bartlett x (Old Home x Farmingdale) | PI 617519 | United States |
| OPR-013 OHxF C-34 | Old Home x Farmingdale | PI 541368 | United States |

typic verification of the 'Farmingdale' and 'Old Home' clones growing at the USDA genebank, and the expanded SSR fingerprinting of these cultivars and several OH×F rootstock selections using a universal fingerprinting set previously described by Evans et al. (2009) that is made up of more polymorphic genomic SSR loci.

## Materials and Methods

*Plant material.* Young, actively growing leaves were collected in the spring of 2007 from the clonal genebank accessions of 'Anjou', 'Old Home', 'Farmingdale', OH×F 51, OH×F 69 (3 sources), OH×F 87, OH×F 97, OH×F 230, OH×F 333 and several standard cultivars in the NCGR orchard collection in Corvallis, Oregon (44.554° lat., -123.222° long.). The OH×F 69 clone in the genebank collection had come from OSU with a note in its inventory record about a possible identity question. In 2008, additional clones of OH×F 69 that trace back to the original Daybreak Nursery tree were obtained from Fowler Nurseries (Newcastle, CA) and North American Plants (McMinnville, Oregon) for comparison.

*DNA extraction.* Thirty to 50 mg of leaf tissue was placed in a cluster tube (Corning, Tewksbury, MA) containing a 4 mm stainless steel bead (McGuire Bearing Company, Salem, OR). The samples were frozen in liquid nitrogen and stored at -80°C, until extraction. Grinding was performed in the Retsch MM301 Mixer Mill, (Retsch, Inc., Hann, Germany) rapidly at a frequency of 30 cycles·s$^{-1}$ using three 30 s bursts. DNA was extracted with the Qiagen protocol described in detail by Gilmore et al. (2011).

*SSR genotyping.* Twelve microsatellite primers that make up a standard primer set proposed by the European Cooperative Program for Plant Genetic Resources (ECPGR) (Evans et al., 2009) were used. A standard set of six reference cultivars (Table 3) was included to allow harmonization of genetic data when comparing results generated in different laboratories and using different separation platforms. The Type-it Microsatellite Multiplex PCR Kit (Qiagen Inc., Valencia, CA) was used to amplify SSRs in two reactions of 15 µL total volume. The 15 µL PCR reaction mix contained: 8.3 µL of 2x Type-it Multiplex PCR Master Mix (Qiagen), 1.7 µL of a 10x multiplex primer mix containing 2 µM of each primer, 1.7 µL Q solution, and 3.3 µL of 3ng·µL$^{-1}$ template DNA. Touchdown amplification was performed with a Tetrad thermocycler (MJ Research, Inc., Watertown, MA) using an initial step of 95°C for 5 min, followed by 10 cycles of 95°C for 30 s, annealing temperatures starting at 62°C for 90 s (decreasing by 1°C/cycle), and 72°C for 30 s for extension. This step was followed by 28 cycles of 95°C for 30 s, 52°C for 90 s, and 72°C for 30 s, with a final extension step of 60°C for 30 min. Success of the PCR was confirmed by 2% agarose gel electrophoresis. Fragment analysis followed separation on a Beckman CEQ 8000 capillary genetic analyzer (Beckman Coulter, Fullerton, CA). Allele sizing and visualization were performed using the fragment analysis module of the CEQ 8000 software. Alleles were scored by fitting the peaks into bins less than one nucleotide. For unweighted pair group method with arithmetic mean (UPGMA) cluster analysis, individuals were scored for the presence or absence of each allele and PowerMarker (Liu and Muse, 2005) was used for cluster analysis.

*Paternity testing.* Paternity analysis for the six OH×F selections included in this study (Table 3) was carried out using a likelihood approach with the CERVUS 3.0 software (Kalinowski et al., 2007). Using the genotype file at the 12 loci, CERVUS was used to determine allele frequency, to simulate paternity analysis and calculate critical values of likelihood ratios. The paternity analysis module (unknown sexes) used the twelve cultivars included in the study as candidate parents. Other parameters set for CERVUS were 0.99 for the proportion of loci typed and 0.022 for rate of genotyping error.

*Phenotype verification.* Fresh fruits and

**Table 3.** Genotypic information at 12 SSR loci for 'Old Home', 'Farmingdale', 6 OH×F selections, and 10 pear cultivars available at USDA-ARS, NCGR. Alleles present in Farmingdale but not observed in any of the OHxF selections are highlighted. Allele mismatches are underlined.

| | CH05c06 | EMPc117 | GD147 | EMPc11 | CH04e04 | CH01f07a | CH03g08 | CH01d09 | CH03d13 | CH02b11 | CH01d10 | GD97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abbe Fetel[a] | 97/115 | 117/119 | 125/125 | 146/152 | 181/199 | 182/192 | 246/250 | 289/297 | 111/115 | 128/128 | 155/157 | 145/153 |
| Anjou | 97/115 | 117/121 | 125/125 | 142/152 | 181/181 | 182/196 | 252/260 | 283/285 | 113/127 | 132/138 | 155/157 | 159/175 |
| Bartlett[a] | 91/95 | 89/117 | 125/125 | 152/152 | 181/207 | 178/186 | 230/246 | 243/279 | 111/127 | 122/128 | 153/161 | 159/175 |
| Comice[a] | 91/91 | 117/117 | 125/131 | 152/156 | 181/199 | 184/186 | 232/236 | 279/285 | 111/115 | 134/138 | 155/161 | 145/153 |
| Conference[a] | 91/101 | 119/121 | 125/125 | 142/152 | 181/207 | 182/194 | 230/260 | 279/285 | 111/127 | 124/128 | 161/161 | 171/199 |
| Farmingdale | 91/115 | 99/121 | 125/125 | 142/142 | 181/181 | 182/190 | 230/260 | 283/285 | 111/113 | 138/138 | 157/161 | 159/175 |
| Harrow Sweet | 91/97 | 113/117 | 125/125 | 152/156 | 181/181 | 186/192 | 246/260 | 243/285 | 111/127 | 122/122 | 153/157 | 153/159 |
| Hosui[a] | 87/109 | 95/107 | 135/137 | 148/148 | 189/189 | 182/204 | 256/262 | 283/283 | 101/101 | 124/134 | 159/159 | 175/175 |
| OH×F 51 | 95/95 | 89/119 | 125/125 | 152/152 | 181/181 | 178/182 | 230/246 | 279/279 | 111/127 | 122/132 | 135/153 | 159/167 |
| OH×F 69 | 91/91 | 89/119 | 125/127 | 152/156 | 181/181 | 186/192 | 230/260 | 279/281 | 115/127 | 128/128 | 135/161 | 159/167 |
| OH×F 87 | 91/91 | 117/117 | 125/127 | 152/152 | 181/207 | 186/192 | 230/246 | 243/281 | 111/115 | 122/132 | 135/153 | 159/173 |
| OH×F 97 | 91/91 | 117/119 | 125/125 | 152/156 | 181/207 | 186/192 | 230/246 | 279/281 | 111/115 | 128/132 | 135/153 | 159/167 |
| OH×F 230 | 95/95 | 89/119 | 125/127 | 152/156 | 181/181 | 178/192 | 230/246 | 279/279 | 111/127 | 128/132 | 135/153 | 159/173 |
| OH×F 333 | 91/95 | 117/119 | 125/127 | 152/152 | 181/181 | 182/186 | 230/230 | 279/279 | 115/127 | 122/132 | 153/157 | 159/173 |
| Old Home | 91/95 | 119/119 | 125/127 | 152/156 | 181/181 | 182/192 | 230/260 | 279/281 | 111/115 | 128/132 | 135/159 | 167/173 |
| Passe Crassane[a] | 91/111 | 101/117 | 125/129 | 152/152 | 181/181 | 182/182 | 230/246 | 279/285 | 127/127 | 132/132 | 157/161 | 159/175 |
| Pyrodwarf | 91/91 | 119/121 | 125/125 | 152/156 | 181/181 | 182/192 | 260/260 | 279/285 | 111/115 | 124/128 | 135/161 | 167/199 |
| Rogue Red | 91/95 | 117/121 | 125/127 | 146/152 | 181/181 | 186/210 | 236/260 | 279/279 | 111/111 | 138/138 | 161/161 | 145/159 |

[a] Reference accessions recommended by Evans et al. (2009) to allow data comparison across collections.

leaves were photographed, or photos were examined from the genebank photo archives for 'Anjou', 'Farmingdale', 'Old Home', and several OH×F selections. Source histories of the genebank cultivars were reviewed and fruit characteristics were compared to published descriptions.

## Results and Discussion

*DNA fingerprints.* Each of the 12 cultivars and OH×F selections were uniquely identified except for the three OH×F 69 selections obtained from different sources which had identical fingerprints (Fig. 3). All OH×F selections shared an allele with 'Old Home' at each of the 12 loci with two exceptions: OH×F 87 was homozygous for 117 at EMPc117 and did not have the 119 allele from 'Old Home'; and OH×F 333 did not have the 135 or 159 alleles present in 'Old Home' at CH01d09 (Table 3). Neither of the two alleles at four SSR loci (EMPc117, EMPc11, CH01d08 and CH02b10) in 'Farmingdale' was found in any of the OH×F selections indicating that 'Farmingdale' is highly unlikely to be the pollen parent for these selections (Table 3). 'Farmingdale' shared an allele with 'Anjou' at each locus (Table 3) confirming the latter as one of the likely parents as previously reported (Bassil and Postman, 2009).

Six of the cultivars selected as references (Evans et al., 2009) were included in this study to standardize microsatellite allele scoring and allow data comparison across collections and separation platforms in the future (Table 3). 'Bartlett' appeared to share one allele at each locus with the OH×F selections (Table 3). Paternity analysis using CERVUS (Kalinowski et al., 2007) was conducted to confirm this possibility. It confirmed 'Old Home' and 'Bartlett' as the most likely parent pair with the highest likelihood at the relaxed confidence level (80%) for OH×F 69, 87 and 333 and at the strict confidence level (95%) for OH×F 51, 97 and 230. No allele mismatches were observed for

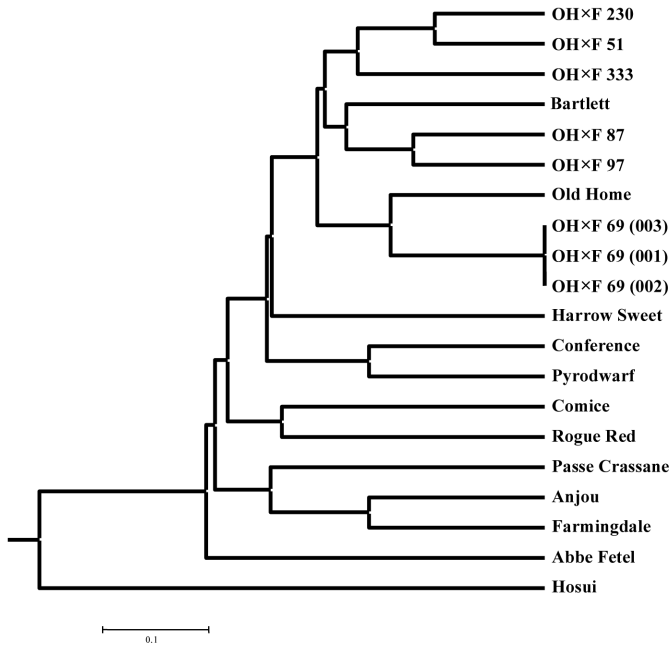


**Fig. 3.** Unweighted pair group method with arithmetic mean (UPGMA) cluster analysis of the evaluated pear cultivars and selection based on 12 SSR loci.

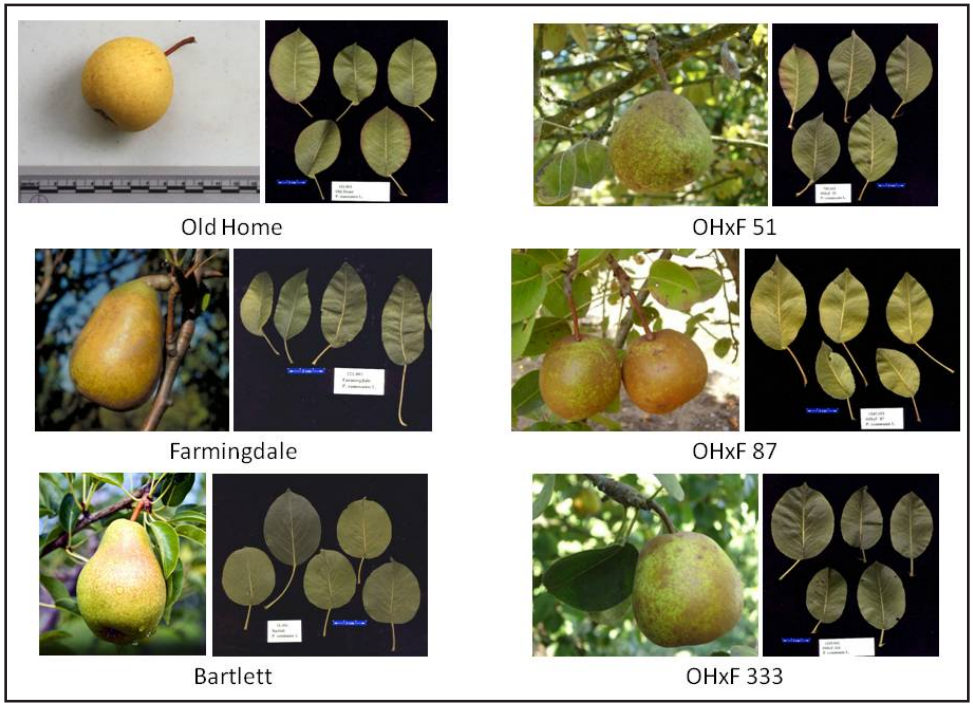


**Fig. 4.** Fruit and leaves of 'Old Home', 'Farmingdale', 'Bartlett' and 3 OH×F selections.

all but OH×F 87 and OH×F 333 which had a single mismatch. The mismatch of one allele at one locus (described above) for these two selections is most likely due to mutation, common at microsatellite sites. This result reveals 'Bartlett' as the original pollen parent for the OH×F clones included in this study. Based on the phenotypes of the 41 OH×F clones in the genebank collection, it is probable that 'Bartlett' was the pollen parent for all of them.

*Cultivar source histories and phenotypes.* Genebank records show that the 'Farmingdale' and 'Old Home' clones were obtained as scions from the original trees that Reimer had established at the Southern Oregon Experiment Station (USDA-ARS, 2012) and identity verification notes indicate that previous visual examination of these cultivars match those of the original trees as described by Hartmann (1957). 'Farmingdale' fruit has a very distinctive shape, not unlike a swollen and slightly elongated 'Anjou' (Fig. 4) with a similar fine texture and good fruit quality. The peduncle is unusually short, thick and swollen where connected to the fruit. 'Old Home' is distinctively and unusually round for a European pear, with a slender peduncle of medium length (Fig. 4). The eating quality of 'Old Home' fruit is remarkably poor. The fruit as grown at NCGR clearly matches the photograph from the variety collection in Ohio taken in the mid 20$^{th}$ century (Howlett, 1957). The various 'Bartlett' and 'Anjou' clones in the genebank collection produce fruit that exactly matches those cultivars in fruit quality, ripening times, and disease susceptibility as they are known from U.S. commercial orchards. We are confident that the 'Farmingdale', 'Old Home', 'Anjou', 'Bartlett' and other five standard reference clones represented at the USDA genebank and used in this study are correctly identified based on their phenotypes. DNA fingerprints of 'Farmingdale' and the six

reference cultivars (Table 3) obtained from the National Fruit Collections (Brogdale Collections) in the UK also exactly match those from the NCGR collection (Evans, personal communication).

All OH×F clones produce fruit that is somewhat similar in size, shape and color (Fig. 4) with crisp, juicy texture and sweet sprightly flavor; although, they differ in maturity dates. All of the OH×F selections resemble 'Old Home', but not 'Farmingdale', in fruit shape and especially in peduncle size. The foliage of the various OH×F selections is similar in leaf length/width ratio, pedicel length and thickness, and pubescence, the latter of which is quite distinct. They all bear some resemblance to the foliage of 'Old Home', but not to 'Farmingdale' which has characteristically lanceolate leaves and less pubescence (Fig. 4).

While 'Bartlett', rather than the more blight resistant 'Farmingdale', may be the pollen parent of the OH×F selections now being used commercially, these OH×F selections have exhibited excellent blight resistance, as well as resistance to pear decline and good fruit production when used as rootstocks for our most important European pear cultivars (Elkins et al., 2012; Lombard and Westwood, 1987). The highly fire blight resistant 'Farmingdale' is apparently very under-represented in the pedigrees of present day pear rootstocks as well as in the parent clones currently being used in rootstock breeding programs. 'Farmingdale' as a parent is not likely to instill dwarfing or precocity traits in a rootstock, however if fire blight resistance is to be an important genetic component of future pear cultivars and rootstocks, the results of Frank Reimer (1925, 1950) should inspire the reconsideration of 'Farmingdale' germplasm in breeding.

Genetic testing of fruit varieties has become increasingly important in improving the efficiency of breeding new varieties (Iezzoni et al., 2010) and has the additional benefit of clarifying pedigrees of existing varieties (Sitther et al., 2012). Kimura et al. (2003) used SSR markers to confirm and revise the paternity of several Japanese pear cultivars. Discovering the paternity of important or historic varieties like the OH×F rootstocks or 'Bing' cherry (*Prunus avium* L.) not only makes interesting news (Warner, 2013), but helps to avoid inbreeding and aids in the identification of sources of useful horticultural and adaptive traits. Future completion of DNA fingerprinting in the USDA pear genebank will help eliminate redundancy in the collection, streamline the introduction and conservation of unique and valuable germplasm accessions, and help breeders better understand the paternity of parents when making crosses to develop improved varieties.

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