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'York' and 'Felix' Hazelnut Pollenizers

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'York' and 'Felix' are two new hazelnut (*Corylus avellana*) pollenizers. They were released by the Oregon Agricultural Experiment Station in Feb. 2012 to provide compatible pollen for cultivars Yamhill, Dorris, Wepster, McDonald and Jefferson. 'York' sheds pollen in midseason and is recommended as a pollenizer for 'Yamhill', 'Dorris', 'Wepster', and 'McDonald'. 'Felix' sheds pollen in late midseason and is recommended as a pollenizer for the late-flowering 'Jefferson'. Nut yields of the new pollenizers are lower than for cultivars but kernel quality is high. The presence of random amplified polymorphic DNA (RAPD) markers linked to a dominant allele from 'Gasaway' indicates that 'York' and 'Felix' have a high level of resistance to eastern filbert blight (EFB) incited by *Anisogramma anomala*. 'Felix' developed no cankers following greenhouse inoculation, and both pollenizers have remained free of cankers over several years of field exposure. The name 'York' honors the slave owned by William Clark who made major contributions to the success of the Lewis and Clark expedition. The name 'Felix' honors Felix Gillet, who imported European hazelnut cultivars to his Barren Hill Nursery in Nevada City, CA, in the 1880s and was a key player in establishing a hazelnut industry in the United States.

Origins

'York', tested as OSU 878.048, was selected from a population of 183 seedlings from a cross of OSU 479.027 × OSU 504.065 made in 1997 (Fig. 1). The pedigree includes germplasm from Greece ('Tombul Ghiaghli'), Italy ('Tonda Gentile delle Langhe' and 'Montebello'), and Spain ('Barcelona' and 'Casina'). Grower selections 'Butler' and 'Compton' are believed to be hybrids of 'Barcelona' and the pollenizer 'Daviana', which is of English origin. A dominant allele from 'Gasaway' confers EFB resistance (Mehlenbacher et al., 1991) to its parent OSU 504.065 and grandparent VR 17-15. Hybrid seeds from the cross were harvested in Aug. 1997, stratified, and planted in flats in the greenhouse as radicles emerged. The resulting seedlings were transplanted to 2.8-L pots and grown in the greenhouse during the Summer of 1998, then moved outdoors to harden before planting in the field in October. The designation OSU 878.048 indicates the row and tree location of the original seedling. 'Felix', tested as OSU 941.016, was selected from a population of 157 seedlings from a cross of OSU 384.095 × 'Delta' made in 1998 (Fig. 1). The pedigree includes germplasm from Greece ('Extra Ghiaghli', which is a clone of 'Tombul' from Turkey), Italy ('Tonda Gentile delle Langhe'), and Spain ('Casina'). 'Delta' carries a dominant allele from 'Gasaway' for resistance to EFB. Hybrid seeds from the cross were stratified and the resulting seedlings grown in the greenhouse and planted in the field as described for 'York' but 1 year later. The designation OSU 941.016 indicates the row and tree location of the original seedling.

The original seedling tree of OSU 878.048 set fewer than 20 nuts in 2001 and they were not harvested. Nuts were harvested from the original seedling tree and evaluated for 4 years (2002–05). OSU 878.048 was propagated by tie-off layerage of the suckers for the first time in 2003 and again in 2004. Rooted layers were lined out in a nursery row for 1 year and then used to plant replicated yield trials. The original tree was moved with a tree spade to the layer beds, after which its suckers were layered annually. The first replicated yield trial was planted in Spring 2005 and the second trial in Spring 2006. Both trials were randomized complete block designs with a single tree of each entry in each block. The first trial had four blocks and the second trial had seven. Standard cultivars were included in the trials (Tables 1 and 2) for comparison, and several additional numbered selections were included in each trial (data not shown). Nut yield and quality data were collected in the third to seventh growing seasons. Although nut yield and kernel quality are less important for pollenizers than for cultivars, they are desirable. Trunk diameters were measured 30 cm above the soil line at the end of the seventh growing season and used to calculate trunk cross-sectional area (TCA) to indicate tree size.

The original seedling tree of OSU 941.016 set a light crop of nuts in 2003. The nuts were harvested from the original seedling tree and evaluated for 4 years (2003–06). The selection was propagated by tie-off layerage of the suckers beginning in 2005. Rooted layers were lined out in a nursery row for 1 year and then used to plant replicated yield trials. OSU 941.016 was included in two replicated yield trials planted in Spring 2007 (the third and fourth trials in Tables 1 and 2), one with four trees and the other with seven, with 'Jefferson' and 'Santiam' as the standards. The EFB-susceptible cultivars Barcelona, Lewis, and Clark were planted in a companion trial adjacent to the third trial.

The incompatibility alleles of 'York' and 'Felix' were determined using fluorescence microscopy (Mehlenbacher, 1997). Incompatibility in hazelnut is of the sporophytic type and is controlled by alleles at the S locus. Hazelnut is diploid, and both alleles are expressed by the stigmas. However, the pollen expresses one or both alleles depending on their position in the dominance hierarchy (Mehlenbacher, 2014). 'York' has incompatibility alleles S_2 and S_{21}; only S_{21} is expressed by the pollen because of dominance. S_{21} is a rare allele inherited from 'Casina', whereas S_2 is a common allele inherited from either F-4 or 'Montebello'. 'York' trees set catkins in high numbers, and pollen is shed in copious quantity in midseason, about with 'Gamma' and 'Daviana'. Detailed notes were recorded weekly on catkin elongation and female flower receptivity in relation to standard cultivars during four winters (fourth to seventh years of the trials). Based on these weekly observations, the duration of the pollen shedding period of 'York' is intermediate to long but shortens when weather is warm. 'York' is a suitable pollenizer for 'Yamhill' (S_8 S_{26}), 'Dorris' (S_1 S_{12}), 'Wepster' (S_1 S_2), 'McDonald' (S_2 S_{15}) (Mehlenbacher et al., 2009, 2013, 2014, 2016), and many other cultivars. However, pollen of 'York' is incompatible on stigmas of 'Casina' (S_{10} S_{21}) and 'Felix' (S_{15} S_{21}) because of the shared allele S_{21}. Pollen of 'Yamhill', 'Dorris', 'Wepster', and 'McDonald' is compatible on 'York' females. 'Felix' has incompatibility alleles S_{15} and S_{21}; both alleles are expressed by the pollen. S_{15} was contributed by 'Delta' (S_1 S_{15}) and S_{21} by 'Casina' (S_{10} S_{21}). The trees set catkins in moderate to high numbers, and the catkins shed copious quantities of pollen in late midseason, about with 'Hall's Giant'. 'Felix' pollen shed overlaps the first half of the time that females of 'Jefferson' (S_1 S_3) (Mehlenbacher et al., 2011) are receptive, which is very late. The combination of 'Felix', 'Eta', and 'Theta' (Mehlenbacher et al., 2012) covers the entire season that 'Jefferson' females are receptive. 'Felix' is also a suitable pollenizer for the late-flowering 'Clark' (S_3 S_8) and 'Ennis' (S_1 S_{11}), but these should be planted only in areas

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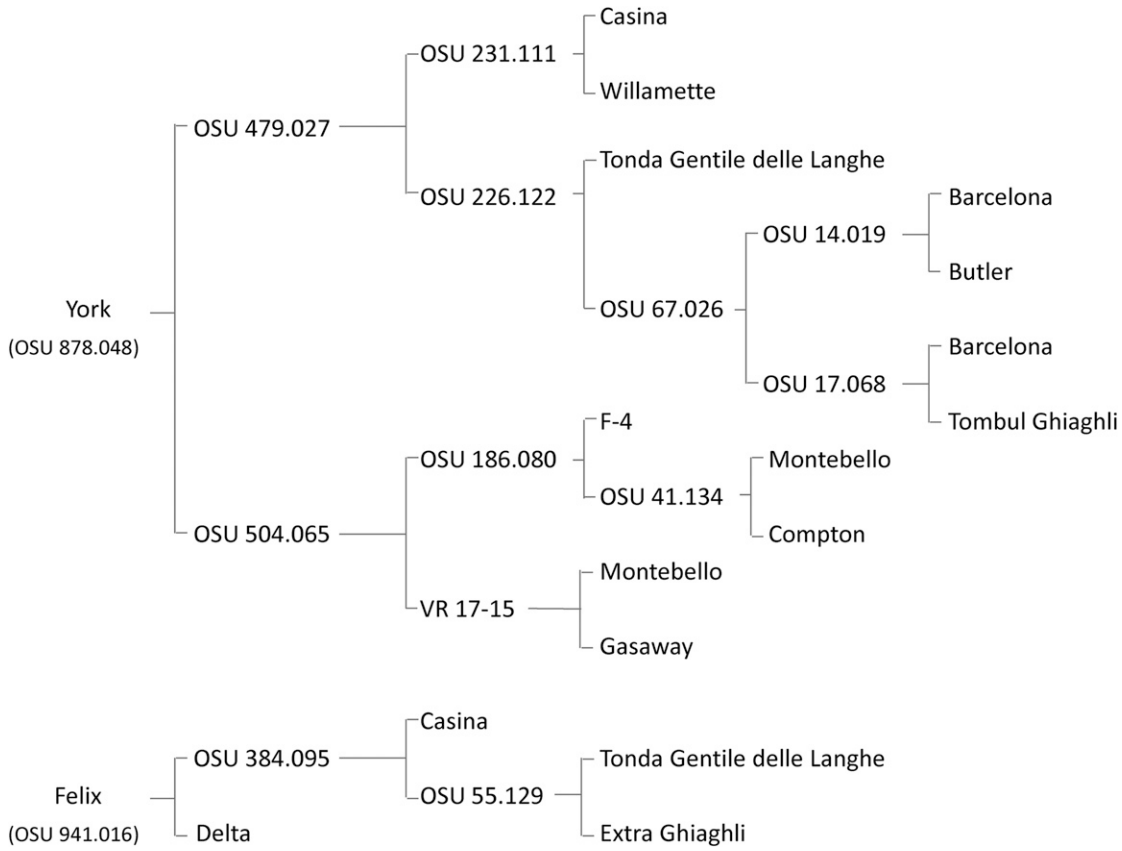

Fig. 1. Pedigrees of 'York' and 'Felix' hazelnut pollenizers. The female parents are shown on top.

where EFB is absent. 'Felix' pollen shed overlaps the end of the receptivity period of females of 'Yamhill', 'Dorris', and 'Wepster'; orchards of these cultivars would benefit from inclusion of a few trees of 'Felix'. Pollen of 'Felix' is incompatible on females of 'McDonald' (S_2 S_{15}), 'Casina' (S_{10} S_{21}), and the pollenizers 'York' (S_2 S_{21}), 'Delta' (S_1 S_{15}), and 'Hall's Giant' (S_5 S_{15}) but is compatible on nearly all other cultivars. Pollen of 'Jefferson', 'Yamhill', 'Dorris', 'Wepster', 'Clark', and 'Ennis' is compatible on females of 'Felix', but pollen of 'McDonald', 'York', 'Casina', 'Delta', and 'Hall's Giant' is incompatible. The releases of pollenizers 'York' and 'Felix' follow the releases of 'Gamma', 'Delta', 'Epsilon', and 'Zeta' in 2001 (Mehlenbacher and Smith, 2004), and of 'Eta' and 'Theta' in 2009 (Mehlenbacher et al., 2012). 'York' and 'Felix' represent improvements over the pollenizers 'Gamma' and 'Delta', respectively.

Descriptions

The 'York' tree is moderately vigorous and has a globose shape, thus facilitating wind dispersal of pollen in the orchard (Fig. 2). In the first trial, TCA at the end of the seventh growing season was similar for 'York' and 'Lewis', which were ≈70% of the size of the vigorous 'Barcelona' (121.6 cm^2). In the second trial, TCA of 'York' was similar to 'Jefferson' and 'McDonald', which are similar in size to 'Lewis'. Cumulative nut

Table 1. Nut yields, trunk cross-sectional area (TCA), yield efficiency, and bud mite ratings of York and Felix in comparison with other hazelnut cultivars in four trials planted in 2005–07 in Corvallis, OR.

	Nut yield (kg/tree) by yr								
Cultivar	Third	Fourth	Fifth	Sixth	Seventh	Total	TCA[z] (cm^2)	Yield efficiency[y] ($kg \cdot cm^{-2}$)	Bud mite rating[x] (1 to 5 scale)
First trial, planted in 2005, four trees per cultivar									
Barcelona	0.74	1.43	5.52	4.73	6.62	19.03	121.6	0.158	1.0
Clark	0.80	2.05	4.75	5.16	6.82	19.57	76.5	0.256	3.0
Dorris	0.35	3.31	4.58	4.65	7.11	20.00	71.2	0.285	1.0
Lewis	1.10	2.26	5.08	6.29	10.72	25.44	80.1	0.320	2.6
York	0.26	0.90	3.85	3.07	8.19	16.26	84.2	0.194	1.1
LSD (0.05)	0.28	0.47	1.06	1.21	1.38	2.70	17.5	0.046	0.6
Second trial, planted in 2006, seven trees per cultivar									
Dorris	0.42	2.84	3.30	6.51	5.70	18.78	84.0	0.225	—
Jefferson	0.41	3.55	3.35	6.97	5.79	20.07	85.4	0.235	—
McDonald	0.29	1.13	2.44	6.54	6.71	17.11	86.9	0.198	—
Sacajawea	0.26	1.92	2.51	6.52	6.76	17.97	93.7	0.196	—
Santiam	0.29	1.76	3.73	7.25	6.34	19.36	79.2	0.244	—
Wepster	0.24	1.56	2.56	6.62	8.68	19.67	99.2	0.198	—
Yamhill	0.78	2.79	3.88	7.34	4.94	19.73	78.5	0.249	—
York	0.41	1.52	2.48	6.13	4.42	14.97	85.6	0.175	—
LSD (0.05)	0.17	0.55	0.75	0.89	1.26	2.62	10.4	0.027	—
Third trial, planted in 2007, four trees per cultivar									
Felix	0.06	1.04	2.91	7.93	4.95	16.88	128.4	0.133	2.0
Jefferson	0.55	1.97	5.63	4.60	10.25	22.99	77.5	0.299	1.2
McDonald	0.15	1.10	4.85	7.38	7.95	21.43	87.6	0.245	1.8
Santiam	0.20	1.11	4.09	5.46	6.83	17.68	66.8	0.267	2.2
LSD (0.05)	0.21	0.43	0.54	2.04	1.18	2.45	13.5	0.029	0.2
Fourth trial, planted in 2007, seven trees per cultivar									
Felix	0.08	1.31	2.65	8.19	5.08	17.13	160.0	0.107	—
Jefferson	1.08	2.44	6.24	5.32	8.84	23.92	90.4	0.266	—
Santiam	0.40	1.90	4.52	6.68	5.09	18.59	82.2	0.227	—
LSD (0.05)	0.15	0.35	0.52	0.78	1.31	1.89	11.2	0.028	—

[z]TCA calculated from trunk diameter 30 cm above the soil line at the end of the seventh growing season.
[y]Yield efficiency = total nut yield/TCA.
[x]Susceptibility to bud mite (primarily *Phytoptus avellanae*) rated annually in the first and third trials on a scale of 1 (no blasted buds) to 5 (many blasted buds).
LSD = least significant difference.

Table 2. Nut and kernel weight, kernel percentage, ratings for fiber and blanching, and frequency of good nuts and defects in four replicated hazelnut trials in Corvallis, OR.

						Frequency (%)[w]							
							Brown					Poor		Black
Cultivar	Nut wt (g)	Kernel wt (g)	Kernel percentage[z]	Fiber[y] (1 to 4 scale)	Blanching[x] (1 to 7 scale)	Good	Blanks	Stain	Moldy	Shriveled	Fill	Twins	Tips
First trial, planted in 2005, four trees per cultivar													
Barcelona	3.90	1.66	42.6	2.8	4.4	69.4	7.0	0.9	3.2	1.5	14.4	3.8	0.3
Clark	2.47	1.26	51.2	2.9	3.4	80.9	2.7	0.8	5.5	1.0	7.6	0.6	1.0
Dorris	3.39	1.45	43.0	2.0	2.4	79.1	7.0	0.6	3.5	0.3	8.7	0.0	1.3
Lewis	2.91	1.38	47.2	1.3	3.9	72.2	2.9	0.1	12.5	1.3	10.3	1.1	1.3
York	2.85	1.32	46.3	2.7	4.4	81.3	9.7	1.1	2.9	0.4	3.9	0.0	1.1
LSD (0.05)	0.28	0.13	1.8	0.6	0.8	7.9	5.6	1.3	4.6	1.6	7.0	1.3	1.4
Second trial, planted in 2006, seven trees per cultivar													
Dorris	3.24	1.32	40.8	—	2.9	80.7	7.5	0.2	4.2	4.3	1.9	0.1	1.2
Jefferson	3.53	1.51	42.8	—	4.8	84.2	3.8	0.1	4.4	2.8	3.8	0.5	0.5
McDonald	2.39	1.21	50.7	—	3.8	88.0	2.7	0.0	1.0	7.5	0.5	0.0	0.3
Sacajawea	2.52	1.29	51.2	—	2.8	87.8	3.1	0.0	3.4	3.1	1.2	0.1	1.3
Santiam	2.09	1.03	49.5	—	5.1	76.2	3.0	0.0	7.9	9.4	2.3	0.2	0.9
Wepster	2.23	0.98	43.9	—	3.1	86.7	7.6	0.2	1.1	2.7	1.4	0.1	0.3
Yamhill	2.18	1.01	46.4	—	5.0	91.3	2.3	0.1	2.2	2.5	1.6	0.0	0.1
York	2.59	1.12	43.4	—	4.8	83.7	8.7	0.3	1.7	2.8	1.2	0.0	1.6
LSD (0.05)	0.23	0.13	3.0	—	0.7	5.6	3.6	0.9	2.2	2.7	2.3	0.5	0.9
Third trial, planted in 2007, four trees per cultivar													
Felix	2.71	1.37	50.8	3.0	2.2	88.9	4.2	0.2	2.1	0.4	2.9	0.3	1.1
Jefferson	3.76	1.67	44.5	3.0	4.3	80.1	4.3	0.3	5.7	0.4	8.9	0.6	0.6
McDonald	2.62	1.37	52.3	2.6	3.3	83.5	5.1	0.1	2.1	4.5	4.5	0.1	0.3
Santiam	2.28	1.15	50.6	3.0	4.2	68.8	2.8	0.1	17.3	1.8	9.6	0.1	0.1
LSD (0.05)	0.22	0.04	1.0	0.1	0.4	3.5	2.5	0.3	2.3	1.0	2.5	0.4	0.5
Fourth trial, planted in 2007, seven trees per cultivar													
Felix	2.40	1.20	50.1	—	2.2	94.6	1.7	0.15	2.1	0.4	0.1	0.3	0.7
Jefferson	3.42	1.47	43.2	—	4.4	90.2	3.4	0.07	4.5	0.1	0.0	0.6	1.1
Santiam	2.02	1.01	49.9	—	4.6	80.5	1.8	0.04	16.4	0.7	0.1	0.0	0.4
LSD (0.05)	0.10	0.04	0.8	—	0.6	3.0	2.0	0.28	2.7	0.8	0.3	0.7	1.0

[z]Kernel percentage = (kernel weight/nut weight) × 100.
[y]Fiber on pellicle rated in the first and third trials from 1 (none) to 4 (much).
[x]Blanching rated in the four trials on a scale of 1 (complete pellicle removal) to 7 (no pellicle removal) after roasting the kernels at 150 °C for 15 min and rubbing.
[w]Mean frequencies of good nuts and defects are based on 100 nuts per tree for 5 yr, 2007–11 in the first trial, 2008–12 in the second trial, and 2009–13 in the third and fourth trials.
LSD = least significant difference.

Fig. 2. Tree of 'York' hazelnut pollenizer in winter with elongated catkins.

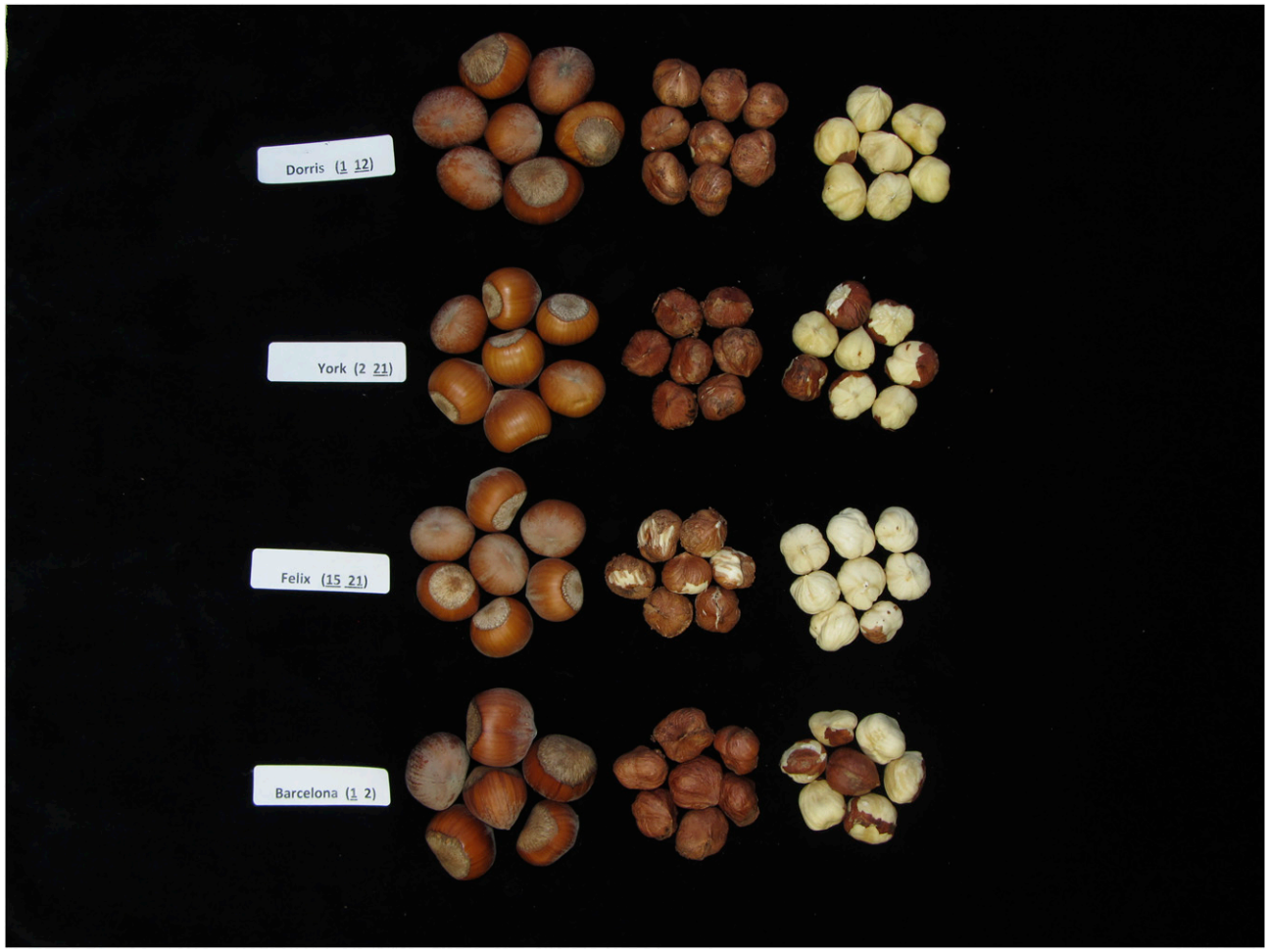

Fig. 3. Nuts and kernels of hazelnuts ‘Dorris’ (top), ‘York’, ‘Felix’, and ‘Barcelona’ (bottom).

Fig. 4. Nuts and husks of ‘York’ hazelnut pollenizer in early September.

Fig. 5. Tree of 'Felix' hazelnut pollenizer in the winter with a few elongated catkins.

yields in the first trial were slightly lower for 'York' (16.26 kg) than for 'Barcelona' (19.03 kg), but yield efficiency is slightly higher (0.19 vs. 0.16 kg·cm^{-2}). In the second trial, cumulative nut yields of 'York' were similar to those for 'Dorris', 'Jefferson', and 'McDonald', but yield efficiency was slightly less than 'McDonald' and 'Sacajawea' (Table 1). The nuts and kernels were attractive (Fig. 3). The nuts were well filled and showed few moldy kernels or other defects in the two trials (Table 2). 'York' nuts were round and of medium size (2.85 g), similar to 'Lewis' (2.91 g) but smaller than 'Barcelona' (3.90 g). The husks were ≈25% longer than the nuts (Fig. 4). Nut maturity was about a week before 'Barcelona', and ≈95% of the nuts fall free of the husk at maturity. The kernels blanch acceptably, with an average rating similar to 'Barcelona'.

'Felix' trees were vigorous and had an upright shape, which facilitates wind dispersal of pollen in the orchard (Fig. 5). In the third and fourth trials, TCA for 'Felix' was higher than for 'Jefferson' and 'Santiam' (Table 1), and similar to the vigorous standard 'Barcelona', which was growing in a trial adjacent to the third trial. 'Felix' nuts were small and nearly round (Fig. 3). Cumulative nut yields were slightly less than

Fig. 6. Nuts and husks of 'Felix' hazelnut pollenizer in early October.

'Santiam', and yield efficiency was low. Nut and kernel weights were similar to 'McDonald' (Table 2) and 'Clark'. Although the pellicle was fibrous, most of the pellicle was removed from the kernels by dry heat and the resulting blanched kernels were bright white and very attractive. The husks were ≈50% longer than the nuts and slit down the side (Fig. 6). Nut maturity was about with 'Barcelona'. About 80% of the nuts fell free of the husk at maturity. Some nuts adhered to the husk at the base, and a few shells were fused to the husk on the side. The frequency of defects, including moldy kernels, was very low (Table 2).

RAPD markers 152-800 and 268-580 that flank the EFB resistance allele in 'Gasaway' (Mehlenbacher et al., 2004) were present in 'York' and 'Felix'. EFB is now present throughout the Willamette Valley (OR) where 99% of the U.S. hazelnut crop is grown. A heavily diseased orchard lies adjacent and upwind of the replicated trials and seedling plots at the Smith Horticultural Research Farm in Corvallis, OR. Trees of 'York' and 'Felix' have been exposed to EFB for more than a decade but have remained free of EFB, although neighboring trees of susceptible cultivars and selections have become infected. 'York' has not been tested in greenhouse inoculations. 'Felix' was included in greenhouse inoculations in 2014 for which procedures were described by Colburn et al. (2015) with 'Ennis' as the highly susceptible check. None of the five 'Felix' trees became infected, whereas all 13 trees of 'Ennis' became infected and developed cankers with stromata. 'Dorris' (six trees), 'McDonald' (six trees), and 'Wepster' (eight trees) also remained free of EFB in this test.

Susceptibility to bacterial blight incited by *Xanthomonas arboricola* pv. *corylina* (formerly *Xanthomonas campestris* pv. *corylina*) has not been quantified, but no trees of 'York' or 'Felix' in the trials were affected. Nevertheless, copper sprays to prevent damage from this pathogen are recommended.

Susceptibility to bud mite (primarily *Phytoptus avellanae*) was rated in the first and third trials (Table 1) after leaf fall once per year for 4 years. The scale was from 1 (no blasted buds) to 5 (many blasted buds). The mean rating for 'York' (1.10) in the first trial indicated high resistance similar to 'Dorris' (1.02) and 'Barcelona' (1.02) and fewer blasted buds than 'Lewis' (2.06) and 'Clark' (2.96). The mean rating for 'Felix' (1.98) in the third trial was higher than 'Barcelona' (1.03) but lower than 'Lewis' (2.30) and 'Clark' (2.79) and indicated moderate resistance. Chemical applications should not be necessary to control bud mite.

Layers of 'York' harvested from the stump of the original seedling tree were rated as medium to large in caliper and well rooted. Layers of 'Felix' were very large in caliper with an adequate, but not abundant, number of roots. Nurseries and the Oregon Hazelnut Commission were annually supplied with information on the performance of 'York' and 'Felix' for a few years before their release. In vitro cultures were established and made available to private companies under material transfer agreements for micropropagation on a commercial scale. Although growth of 'York' and 'Felix' was slow in the first cultures distributed, multiplication rates have improved and are now similar to those of other releases.

Of the four pollenizers released in 2001, 'Gamma' and 'Delta' were widely used as pollinizers for 'Lewis', whose female inflorescences are receptive in midseason. 'York' represents an improvement over 'Gamma' in that its catkins shed pollen over a longer period of time, the trees are less susceptible to bud mites, and its kernels are more attractive. 'Felix' and 'Delta' shed pollen over an extended period of time, but 'Felix' represents an improvement over 'Delta' in that its trees are more vigorous and fewer kernels have pellicles with a greasy appearance. The tree vigor improves pollen dispersal by wind in the orchard. 'Felix' also represents improvements over the standard pollinizer 'Hall's Giant', which sheds pollen at the same time. 'Felix' is EFB resistant, sheds pollen over a long time, and its nuts are well-suited to the kernel market, whereas 'Hall's Giant' is EFB susceptible, sheds pollen over a short time, and has low yields of large nuts. 'Delta' pollen (S_1 S_{15}) is incompatible on females of 'Jefferson' (S_1 S_3), as well as 'Dorris' (S_1 S_{12}) and 'Wepster' (S_1 S_2)

because of the common allele S_1, whereas 'Felix' pollen is compatible. 'York' and 'Felix' will provide Oregon's hazelnut growers more options when establishing new orchards. In older orchards, pollenizers represent ≈11% of the total number of trees. In recent years, 5.5% is more common, but nut yields sometimes suffer because of insufficient pollination. The planting of three pollenizers that shed pollen at different times during the winter flowering season is recommended, as this increases the likelihood that females of the main cultivar will be pollinated. 'York' and 'Felix' catkins shed copious amounts of pollen. They have been used as pollen parents in controlled pollinations and nut set was very good.

Availability

'York' and 'Felix' are protected by U.S. Plant Patents 24,972 and 24,973, respectively. Interested nurseries should contact the Office for Commercialization and Corporate Development, 312 Kerr Administration Building, Oregon State University, Corvallis, OR, 97331-2140. Licensing agreements will be issued to nurseries in the United States on a nonexclusive basis, with sales limited to the United States. The license calls for a royalty payment for each tree sold. Nurseries in other countries interested in an exclusive licensing agreement for a specified geographic area should contact OSU-OCCD. Information and small quantities of scion wood for research may be obtained from S.A. Mehlenbacher. Trees of 'York' and 'Felix' are available from nurseries.

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