'Jefferson' Hazelnut

Shawn A. Mehlenbacher¹, David C. Smith, and Rebecca L. McCluskey
Department of Horticulture, 4017 Agricultural and Life Sciences Building,
Oregon State University, Corvallis, OR 97331

Additional index words. *Corylus avellana*, filbert, *Anisogramma anomala*, eastern filbert blight, nut breeding

'Jefferson' is a new hazelnut (*Corylus avellana* L.) cultivar for the in-shell market. It was released by the Oregon Agricultural Experiment Station in Jan. 2009 as a replacement for 'Barcelona'. It combines complete resistance to eastern filbert blight (EFB) caused by the fungus *Anisogramma anomala* (Peck) E. Müller with high nut yield, large nut size, and good kernel quality. Compared with 'Barcelona', Oregon's leading cultivar, 'Jefferson' has smaller trees, higher nut yield, and much higher nut yield efficiency. Pellicle removal ratings are better than 'Barcelona', and kernel quality is suitable for use in chocolate products and baked goods, although kernel size is larger than ideal for the kernel market. 'Jefferson' is recommended for Oregon's Willamette Valley and other areas with a similar climate.

Origin

'Jefferson', tested as OSU 703.007, resulted from a cross of OSU 252.146 × OSU 414.062 made in 1993 by Shawn A. Mehlenbacher and David C. Smith (Fig. 1). Hybrid seeds were harvested in Aug. 1993, stratified, and the resulting seedlings grown in the greenhouse during the summer of 1994. In Oct. 1994, 144 seedlings from this cross were planted in the field. This same progeny was used to construct a linkage map for hazelnut (Mehlenbacher et al., 2006). The designation OSU 703.007 indicates the row and tree location of the original seedling. Nuts were first observed on the original seedling in Sept. 1998. Nuts were harvested from the original seedling tree and evaluated in 1998 and in each of the next 3 years. OSU 703.007 was propagated by tie-off layerage of the suckers in the summer of 2000. The resulting trees were lined out in a nursery row the next year and then used to plant two replicated yield trials in the spring of 2002. Eight trees of each genotype were planted in the first trial and four trees of each in the second trial. The trials were located at the Smith Horticulture Research Farm in Corvallis and planted as

randomized complete block designs with a single tree of each genotype in each block. 'Lewis', 'Clark', and Oregon's leading cultivar, Barcelona, were included as checks. Several additional numbered selections were included in both trials. The name 'Jefferson' is in honor of the third U.S. president, who sent Meriwether Lewis and William Clark to explore the Louisiana Purchase. Mt. Jefferson is the second highest mountain in Oregon.

Description

Trunk diameter was measured 30 cm above the soil line at the end of the growing

Fig. 1. Pedigree of 'Jefferson' hazelnut.

Table 1. Nut yield, tree size, and yield efficiency of 'Jefferson' and other hazelnut cultivars and selections in two hazelnut trials planted in 2002.

Selection	No. of trees	Nut yield (kg·tree ⁻¹)						TCA ^z (cm ²)	Yield efficiency ^y (kg·cm ⁻²)
		2004	2005	2006	2007	2008	Total		
First trial									
OSU 688.010	8	0.23	1.06	4.43	4.14	5.02	14.89	79.0	0.190
Barcelona	8	0.38	1.35	5.63	5.16	4.42	16.94	115.9	0.147
Clark	8	0.24	2.21	3.90	3.76	5.80	15.91	64.1	0.248
Jefferson	8	0.46	2.18	5.58	5.14	7.02	20.38	78.2	0.261
Lewis	8	0.42	2.84	4.35	6.40	6.28	20.29	84.4	0.242
LSD (0.05)		0.18	0.55	0.81	0.84	1.03	2.37	10.8	0.024
Second trial									
OSU 684.104	4	0.09	1.12	6.15	4.64	5.71	17.70	116.5	0.153
OSU 688.012	4	0.26	2.15	4.85	3.84	6.50	17.60	103.0	0.172
OSU 688.013	4	0.07	0.85	3.71	3.53	5.79	13.95	78.4	0.179
OSU 713.068	4	0.35	2.20	3.33	3.29	5.10	14.28	75.3	0.189
Barcelona	4	0.47	1.56	4.60	4.26	3.95	14.84	100.6	0.149
Clark	4	0.17	2.61	3.77	3.27	6.60	16.42	64.4	0.255
Jefferson	4	0.26	0.24	5.30	3.91	7.06	18.89	63.3	0.299
Lewis	4	0.31	2.79	4.30	5.86	6.31	19.56	72.9	0.268
Zeta	4	0.17	0.59	2.29	2.64	3.86	9.55	108.5	0.088
LSD (0.05)		0.20	0.54	0.95	1.16	1.58	3.0	15.3	0.038

^zTCA = trunk cross-sectional area (cm²).

^yYield efficiency = total yield (2004–08)/TCA.

LSD = least significant difference.

season, in Dec. 2008, and used to calculate trunk cross-sectional area (TCA). TCA provides an estimate of tree size. In the first trial (Table 1), tree size of 'Jefferson' was 67% of the vigorous standard 'Barcelona', slightly smaller than 'Lewis' (73%), and slightly larger than 'Clark' (55%). Total nut yield per tree (third to seventh leaf) was 20.38 kg for 'Jefferson' versus 16.94 kg for 'Barcelona' or 120.3% of the control. Nut yield efficiency, which adjusts for differences in tree size, was much higher for 'Jefferson' (0.261 kg·cm⁻²) than for 'Barcelona' (0.147 kg·cm⁻²), or 178% of the control. In the second trial (Table 1), TCA of 'Jefferson' was 63% of the vigorous standard 'Barcelona', approximately the same as 'Clark' (64%), and slightly smaller than 'Lewis' (72%). Total nut yield per tree (third to seventh leaf) was 18.9 kg for 'Jefferson' compared with 14.8 kg for 'Barcelona', or 127% of the control. Yield efficiency was much higher for 'Jefferson' (0.298 kg·cm⁻²) than for 'Barcelona' (0.149 kg·cm⁻²), or 201% of the control. Because kernel percentage (the ratio of kernel weight to nut weight) is slightly higher for 'Jefferson' (45.0%) than 'Barcelona' (42.9%) (Table 2), yields of kernels per hectare are expected to be much higher than for 'Barcelona'. 'Jefferson' trees have a more upright growth habit than 'Barcelona' (Fig. 2), making them easy to train as single-trunk trees and manage in an orchard. Occasional pruning is desirable to allow sunlight to penetrate the canopy. In Oregon, orchards of the vigorous 'Barcelona' are planted at a spacing of 6 × 6 m. Closer spacing of trees in the orchard would be appropriate to take advantage of the higher nut yield efficiency of 'Jefferson'. 'Jefferson' is suitable for planting at double density (3 m × 6 m) with removal of half of the trees when the branches of neighboring trees begin to touch.

'Jefferson' nuts are borne in clusters of two to three in husks ≈50% longer than the nuts. Some husks are slit down the side,

Received for publication 28 Dec. 2010. Accepted for publication 24 Jan. 2011.

The OSU hazelnut breeding program is supported by State, Hatch Act and Oregon Hazelnut Commission funds, and a specific cooperative agreement with the U.S. Dept. of Agriculture.

A technical paper of the Oregon Agricultural Experiment Station.

¹To whom reprint requests should be addressed; e-mail mehlenbs@hort.oregonstate.edu.

Table 2. Ten-nut weight, 10-kernel weight, and ratings for fiber, pellicle removal, and bud mite susceptibility for 'Jefferson' and other hazelnut cultivars and selections in the second trial planted in 2002.

Selection	10-Nut wt (g) ²	10-Kernel wt (g)	Kernel percentage	Fiber	Blanching	Bud mite rating ³
OSU 684.104	27.26	13.90	51.04	3.2	2.9	1.8
OSU 688.012	28.73	13.38	46.62	3.0	3.4	1.0
OSU 688.013	26.70	11.48	43.03	3.3	3.6	1.8
OSU 713.068	28.75	13.91	48.36	2.2	3.9	1.9
Barcelona	37.89	16.23	42.93	2.8	4.5	1.0
Clark	25.70	13.03	50.67	2.7	3.7	2.7
Jefferson	36.94	16.61	45.01	2.8	3.9	1.1
Lewis	29.04	13.45	46.36	1.1	4.4	2.4
Zeta	25.92	12.61	48.69	2.3	4.7	1.6
LSD (0.05)	0.71	0.33	0.47	0.1	0.3	0.3

²Means for nut and kernels are over 4 years (2005–2008).

³Susceptibility to bud mite (primarily *Phytoptus avellanae* Nal.) was rated on four trees of each genotype in early winter on a scale of 1 (no blasted buds) to 5 (many blasted buds). Shown are mean ratings for 3 years (2006–2008).

LSD = least significant difference.

Fig. 2. Tree of 'Jefferson' hazelnut.

whereas others form a tube that loosely holds the nuts at maturity. Approximately 80% of the nuts fall free at maturity (range, 60% to 95%). The other nuts come out of the husks as they move through the harvester. Harvest date is estimated to be the same as with 'Barcelona' or up to 3 d later (data not shown). This is unfortunate, because in many years, harvest would coincide with the start of the rainy season in the Willamette Valley.

'Jefferson' was released for the in-shell market as a replacement for 'Barcelona'. The nuts and kernels are similar in size to 'Barcelona' (Fig. 3). The raw kernels of 'Jefferson'

have much fiber on the pellicle, similar to 'Barcelona'. Pellicle removal (blanching) ratings are slightly better for 'Jefferson' than 'Barcelona' (Table 2). When lightly roasted (150 °C for 15 min) and rubbed, more than half of the pellicle is removed. Although 'Jefferson' is being released for the in-shell market, its kernel quality is suitable for many end uses, including chocolate products and baked goods. Kernel diameter, however, is larger than the 11 to 13 mm desired by most buyers. Kernel texture, flavor, and aroma have been given good ratings by researchers and growers. A high percentage of the nuts and kernels of 'Jefferson' are marketable (Table 3). The frequency of blanks, poorly filled nuts, and doubles is less in 'Jefferson' than in 'Barcelona' (Table 3), whereas the frequency of moldy kernels is similarly low. 'Jefferson' nuts occasionally have hairline splits along the sutures where the two halves of the shell join at the apex. This is reflected in the frequency of kernels with black tips (Table 3). The low frequency of split sutures does not appear to warrant great concern.

'Jefferson' trees set a moderate to high number of catkins that shed copious amounts of pollen late in the season, after 'Gamma' and 'Daviana' but before 'Epsilon', 'Zeta', and 'Eta'. Pollen has been collected and used in several controlled pollinations, and both quantity and viability appear to be very good. Styles emerge from female inflorescences of 'Jefferson' late in the season, so pollenizers that shed compatible pollen very late in the season are needed. 'Jefferson' has incompatibility alleles S_1 and S_3 as determined by fluorescence microscopy. Both alleles are expressed in the females but only S_3 is expressed in the pollen because of dominance. Three pollenizers that shed pollen at different times during the period that female inflorescences are receptive are recommended to increase the likelihood that they will be pollinated. 'Eta' and 'Theta' are recommended in a ratio of 1:2 with pollenizers representing 11% of the trees in an orchard. Pollenizers with complete resistance to EFB would eliminate the need for fungicide control in the entire orchard. Pollen of 'Gamma' (S_2 S_{10}) and 'Yamhill' (S_8 S_{26}), which shed pollen in midseason, would overlap the earliest females of 'Jefferson' in some years, but their presence in the orchard should not exceed 20% of the pollenizers. The late pollen of 'Epsilon' and 'Zeta' expresses S_1 and is thus incompatible on 'Jefferson' females. The late pollen of 'Jemtegaard #5' expresses S_3 and is also incompatible on 'Jefferson' females.

'Jefferson' has complete resistance to EFB conferred by a dominant allele from 'Gasaway'. Trees of 'Jefferson' were inoculated in the greenhouse in 2001 with fungal spores of *Anisogramma anomala* as described by Lunde et al. (2000). Enzyme-linked immunosorbent assay (Coyne et al., 1996) 6 months after inoculation failed to detect presence of the fungus. Random amplified polymorphic DNA (RAPD) markers UBC 152₈₀₀ and UBC 268₅₈₀ that flank the resistance allele in 'Gasaway' (Mehlenbacher et al., 2004) are present

Fig. 3. Blanched kernels (top), raw kernels (middle), and nuts (bottom) of 'Barcelona' (left column) and 'Jefferson' hazelnuts (right column).

Table 3. Frequency of nut and kernel defects in 'Jefferson' and other hazelnut cultivars and selections in two hazelnut trials planted in 2002.

Selection	Frequency (%) ²							
	Good ³	Blanks	Brown stain	Moldy	Shrivels	Poor fill	Twins	Black tips
First trial								
OSU 688.010	98.4	1.1	0.0	0.2	0.6	4.6	0.0	0.1
Barcelona	86.6	5.6	0.0	4.6	6.0	4.2	4.8	0.0
Clark	96.1	1.0	0.1	1.4	1.5	4.9	1.0	0.9
Jefferson	94.2	1.1	0.0	2.1	1.0	5.5	0.2	1.6
Lewis	89.8	0.4	0.0	6.6	4.7	7.5	1.5	1.0
LSD 0.05	3.5	1.6	0.2	1.9	2.6	3.9	1.2	1.0
Second trial								
OSU 684.104	81.6	4.2	0.4	2.1	1.8	9.7	0.2	0.4
OSU 688.012	84.2	8.7	0.2	2.0	0.4	3.6	0.3	0.6
OSU 688.013	95.6	2.0	0.1	0.2	0.3	1.8	0.0	0.1
OSU 713.068	86.8	3.6	0.1	0.9	0.9	7.6	0.0	0.3
Barcelona	63.6	6.0	1.5	2.6	1.6	21.8	4.0	0.1
Clark	79.6	2.7	1.8	3.0	0.8	11.6	0.6	0.6
Jefferson	76.2	4.1	0.3	3.0	0.9	14.2	0.4	1.2
Lewis	67.6	2.6	0.3	7.8	3.6	19.1	1.0	0.1
Zeta	80.1	9.7	0.4	2.3	0.8	5.1	1.6	0.3
LSD 0.05	3.8	1.7	0.5	1.3	1.1	3.4	0.8	0.5

²Means of 4 years (2005–2008).

³Good nuts are "marketable nuts" in the first trial, because the counts include some shrivels and poor fill. The counts are shown separately for the second trial.

LSD = least significant difference.

in 'Jefferson' as are all RAPD markers between them. 'Jefferson' trees in orchards in the northern Willamette Valley adjacent to infected trees of susceptible cultivars have remained free of disease. 'Jefferson' is heterozygous and transmits resistance to half of its seedlings. EFB is now present throughout the Willamette Valley where 99% of the U.S. hazelnut crop is grown. Pruning to remove cankers and fungicide applications are currently used to manage the disease in orchards of 'Barcelona' and other susceptible cultivars. Like 'Yamhill', released in Jan. 2008 (Mehlenbacher et al., 2009), 'Jefferson' is suitable for planting in areas with high disease pressure. The response of 'Jefferson' to inoculation with other isolates of EFB from the eastern United States has not been tested. Inoculations to date have been only with the Oregon isolate.

Susceptibility to bacterial blight caused by *Xanthomonas campestris* pv. *corylina* has not been quantified, but two of the four trees in the second trial appear to have been affected. They had a stressed appearance at the end of the growing season, and one tree showed liquid oozing from a crack where a large scaffold limb joined the main trunk. Several siblings in the original seedling block

showed shoot dieback, which is a typical symptom of bacterial blight. Shoot dieback was noted in some 'Jefferson' plantings in grower orchards, particularly after the cool, wet spring of 2008. These observations indicate a level of susceptibility comparable to the standard 'Barcelona'. Copper sprays to minimize damage from this pathogen are recommended.

Susceptibility to bud mite (primarily *Phytoptus avellanae* Nal.) was rated in the second replicated trial (Table 2) after leaf fall once per year for 3 years (Dec. 2006–2008). The scale was from 1 (no blasted buds) to 5 (many blasted buds). The average ratings indicate a high level of resistance for 'Jefferson' (1.08) and 'Barcelona' (1.00), moderate resistance for 'Lewis' (2.40), and an intermediate response for 'Clark' (2.73). Because blasted buds are very rare on 'Jefferson', chemical applications should not be necessary to control bud mite.

Layers generally root easily and abundantly. Rooted layers are vigorous and similar in height and caliper to those of 'Barcelona'. Scions of 'Jefferson' were first distributed to nurseries in January 2002 and annual updates provided subsequently. Nurseries were instructed to propagate additional trees 1 year

before the formal release of 'Jefferson'. In vitro cultures of 'Jefferson' were first established at Oregon State University (OSU) in 2002. The cultures have performed very well with multiplication rates higher than for most other cultivars. Cultures were made available to private companies for micropropagation on a commercial scale. Several interested growers established trials of 'Jefferson' in their orchards before its release. Many orchards have been established in the Willamette Valley using micropropagated trees.

Availability

'Jefferson' was released as a public cultivar and may be propagated in the United States without restriction. A list of micropropagators and nurseries, and small quantities of scion wood, may be obtained from S.A. Mehlenbacher. A licensing agreement between OSU and Viveros Nefuen Ltda. (Hijuelas, Chile) granted that company the exclusive right to propagate and sell trees of 'Jefferson' in South America. Legal protection is being sought in Chile, and OSU reserves the right to seek legal protection in other countries for a period of 6 years after release. Nurseries in other countries interested in a licensing agreement for 'Jefferson' should contact the Technology Transfer Office at OSU.

Literature Cited

- Coyne, C.J., S.A. Mehlenbacher, R.O. Hampton, J.N. Pinkerton, and K.B. Johnson. 1996. Use of ELISA to rapidly screen hazelnut for resistance to eastern filbert blight. *Plant Dis.* 80:1327–1330.
- Lunde, C.F., S.A. Mehlenbacher, and D.C. Smith. 2000. Survey of hazelnut cultivars for response to eastern filbert blight inoculation. *HortScience* 35:729–731.
- Mehlenbacher, S.A., R.N. Brown, J.W. Davis, H. Chen, N.V. Bassil, D.C. Smith, and T.L. Kubisiak. 2004. RAPD markers linked to eastern filbert blight resistance in *Corylus avellana*. *Theor. Appl. Genet.* 108:651–656.
- Mehlenbacher, S.A., R.N. Brown, E.R. Nouhra, T. Gokirmak, N.V. Bassil, and T.L. Kubisiak. 2006. A genetic linkage map for hazelnut (*Corylus avellana* L.) based on RAPD and SSR markers. *Genome* 49:122–133.
- Mehlenbacher, S.A., D.C. Smith, and R. McCluskey. 2009. 'Yamhill' hazelnut. *HortScience* 44:845–847.