'Sacajawea' 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*, *Anisogramma anomala*, eastern filbert blight, nut breeding

'Sacajawea' is a new hazelnut (*Corylus avellana* L.) cultivar for the kernel market. It combines a high level of quantitative resistance to eastern filbert blight caused by the fungus *Anisogramma anomala* (Peck) E. Müller with excellent kernel quality and acceptable nut yields. Compared with Oregon's leading cultivar, 'Barcelona', 'Sacajawea' has slightly smaller trees, slightly higher nut yield efficiency, earlier nut maturity, higher percentage of kernel (the ratio of kernel to nut weight), and better pellicle removal ratings. The excellent kernel quality is comparable to the best Italian cultivars.

Origin

'Sacajawea' is the result of a cross of OSU 43.091 × 'Sant Pere' made in 1990 by Shawn A. Mehlenbacher and David C. Smith. 'Sant Pere', a minor cultivar from Tarragona (Spain) with very early nut maturity, was described by Tasis-Valls (1975). We believe that OSU 43.091 resulted from self-pollination of 'Montebello', which is partially self-compatible (Mehlenbacher and Smith, 1991). Alternatively, the pollen parent of OSU 43.091 might be an unknown cultivar or OSU selection. 'Montebello', a Sicilian cultivar, was described by Manzo and Tamponi (1982) and is grown under many synonyms, including 'Nocchione', 'Nostrale', 'Comune di Sicilia', 'Siciliana', and 'Santa Maria del Gesù'.

Hybrid seeds from the cross OSU 43.091 × 'Sant Pere' were harvested in Aug. 1990, stratified, and the resulting seedlings grown in the greenhouse during the summer of 1991. In Oct. 1991, 135 seedlings from this cross were planted in the field. The location designation OSU 540.130 for 'Sacajawea' indicates the row and tree within the row of the original seedling. A few nuts were first observed on the original seedling in Sept. 1994 but were not harvested. Nuts were harvested and evaluated in each of the next 4 years. The selected tree was propagated by tieoff layerage of the suckers in the summer of 1997. The resulting rooted layers were lined out in a nursery row in 1998 and used to plant a replicated yield trial in the spring of 1999 at the Smith Horticulture

Research Farm in Corvallis. Four trees of each genotype were planted in a randomized complete block design with a single tree of each genotype in each block. Oregon's leading cultivar, 'Barcelona', and the recently released 'Lewis' and 'Clark' were included as checks. Nuts were harvested and evaluated annually for 5 years (2001 to 2005). The name was chosen to honor the Shoshone woman who accompanied Meriwether Lewis and William Clark and their Corps of Discovery to the Oregon Territory. They spent the winter of 1805 to 1806 near Astoria, OR.

Description

Trees of 'Sacajawea' were ≈86% of the size of the vigorous standard 'Barcelona' and larger than 'Lewis' (65%) and 'Clark' (59%) as measured by trunk cross-sectional area, 30 cm above the soil line, at the end of the seventh growing season (Dec. 2005) (Table 1). They have a desirable globose growth habit that should be easy to manage in a commercial orchard, but occasional pruning will be necessary to allow sunlight to penetrate the canopy. Total nut yield per tree (third to seventh leaf) was 15.1 kg for 'Sacajawea' versus 16.1 kg for 'Barcelona' or 93.9% of the control. Yield efficiency, which adjusts for differences in tree size by dividing yield by trunk cross-sectional area, was slightly higher for 'Sacajawea' (0.147 kg·cm⁻²) than for 'Barcelona' (0.136 kg·cm⁻²), or 108.5% of the control. Slightly closer spacing of trees in the orchard would be appropriate to take advantage of the higher yield efficiency. Because kernel percentage (the ratio of kernel weight to nut weight) (Table 2) is considerably higher for 'Sacajawea' (52%) than 'Barcelona' (43%), yields of kernels per acre would be higher than for 'Barcelona'.

The nuts of 'Sacajawea' are borne in clusters of two to three in husks equal in length to the nuts. The husks are slit down the side and ≈97% of the nuts fall free at maturity. The nuts are ready to be mechanically harvested 10 to 14 d before 'Barcelona', or approximately the third week in September in Corvallis, OR. The earlier maturity is a significant improvement, because in most years, harvest of 'Sacajawea' will be completed before the start of the rainy season, which coincides with the beginning of the 'Barcelona' harvest.

'Sacajawea' is being released for the kernel market, although it may also be accept-

able for the in-shell market. The nuts and kernels are smaller than 'Barcelona' but larger than 'Clark' and slightly larger than 'Lewis' (Table 2). Chocolate makers prefer kernels 11 to 13 mm in diameter; kernels of 'Clark' and 'Tonda Gentile delle Lange' are of this size. 'Sacajawea' kernels are larger, similar to 'Tonda di Giffoni' and 'Tonda Romana'. Raw kernels are attractive and have a light brown pellicle with a small amount of attached fiber (Table 2). More than half of the pellicle is removed from the kernels with dry heat in the blanching process, yielding kernels that are bright white. Blanching ratings have averaged two to three, which is better than 'Barcelona' and 'Lewis' and similar to 'Clark'. Kernel texture, flavor, and appearance are worthy of a premium price.

'Sacajawea' produces fewer nut and kernel defects than 'Barcelona', particularly fewer poorly filled nuts and blanks (shells lacking kernels) (Table 3). The frequency of moldy kernels is low and similar to 'Barcelona'. Kernel mold was a problem in 2005 in 'Lewis' but was minimal in 'Sacajawea'.

Incompatibility in the diploid European hazelnut is of the sporophytic type and controlled by a single S-locus with multiple alleles (Mehlenbacher, 1997a). 'Sacajawea' has incompatibility alleles S₁ and S₂₂ as determined by fluorescence microscopy (Mehlenbacher, 1997b). Both alleles are expressed in the females but only S₁ is expressed in the pollen because of dominance. The paternal parent 'Sant Pere' has alleles S₂₂ and S₂₆. The maternal parent OSU 43.091 (S₁ S₁) is listed as from a cross of 'Montebello' (S₁ S₂) and the grower selection 'Compton' (S₂ S₃). OSU 43.091 (S₁ S₁) closely resembles 'Montebello', but neither S-allele of 'Compton' is present. The alleles of OSU 43.091 are consistent with what would be expected from self-pollination of 'Montebello', which is partially self-compatible (Mehlenbacher and Smith, 1991). Alternatively, the pollen parent of OSU 43.091 might be an unknown cultivar or OSU selection.

'Sacajawea' trees have a moderate set of catkins that shed copious amounts of pollen early in the season with 'Barcelona'. Pollen has been collected and used in several controlled pollinations, and both quantity and viability appear to be very good. Female inflorescences of 'Sacajawea' emerge early in the season, approximately with 'Barcelona'. Pollenizers that shed pollen early or in midseason would be suitable. We encourage the planting of three pollenizers that shed pollen at different times during the period that female inflorescences are receptive to increase the likelihood that they will be pollinated. 'Lewis' (S₃ S₈) and 'Sacajawea' (S₁ S₂₂) are cross-compatible in both directions and could serve as pollenizers for each other. 'Gamma' (S₂ S₁₀) and 'Hall's Giant' (S₅ S₁₅) are also suitable pollenizers. These four ('Sacajawea', 'Lewis', 'Gamma', and 'Hall's Giant') are cross-compatible in all combinations. Pollen of 'Barcelona' (S₁ S₂) and 'Delta' (S₁ S₁₅) expresses S₁ and is thus

Received for publication 30 Aug. 2007. Accepted for publication 5 Oct. 2007.

A technical paper of the Oregon Agricultural Experiment Station.

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

Table 1. Nut yield, trunk cross-sectional area, yield efficiency, and bud mite ratings of Sacajawea in comparison with other hazelnut cultivars and selections in a trial planted in Corvallis in 1999.^z

Selection	Nut yield (kg)					TCA ^y (cm ²)	YE ^x (kg·cm ⁻²)	BBM ^w
	2001	2002	2003	2004	2005			
Clark	0.88	1.53	2.88	3.38	8.93	17.61	70.2	0.252
Lewis	1.25	1.35	3.81	4.27	8.20	18.88	78.4	0.240
OSU 228.084	0.12	1.13	2.42	5.43	7.36	16.46	96.5	0.170
OSU 553.090	0.49	1.62	2.88	6.50	3.39	14.88	94.1	0.160
Sacajawea	0.23	1.23	3.02	4.89	5.73	15.11	102.8	0.147
Barcelona	0.53	1.10	3.55	4.63	6.28	16.09	119.7	0.136
LSD (0.05)	0.21	0.43	0.74	1.18	1.11	2.51	13.3	0.032
Italian cultivars (single trees)								
Tonda di Giffoni	0.89	2.18	4.38	6.13	4.33	17.91	70.1	0.255
Tonda G. d. Langhe ^v	0.02	0.25	0.54	1.05	1.46	3.32	71.6	0.046
Tonda Romana	0.18	0.61	1.61	3.54	3.84	9.78	71.6	0.137

^zValues are means of four trees of each genotype.

^yTCA = trunk cross-sectional area calculated from trunk diameter 30 cm above the soil line in Dec. 2005.

^xYield efficiency = total yield/trunk cross-sectional area.

^wBBM = frequency of buds blasted by mites (primarily *Phytoptus avellanae*) rated on a scale of 1 (none) to 5 (many). Averages of ratings in winter 2002, 2003, and 2005.

^vTonda Gentile delle Langhe.

LSD = least significant difference.

Table 2. Descriptions of nuts and kernels of hazelnut selections in trial planted in 1999.

Genotype	Nut wt ^z	Kernel wt ^y	Kernel percentage ^x	Fiber ^w	Pellicle removal ^v
OSU 228.084	2.42	1.17	48.3	2.5	1.5
Sacajawea	2.79	1.45	52.1	1.2	2.9
OSU 553.090	2.51	1.17	46.5	2.9	4.1
Barcelona	3.85	1.66	43.1	2.8	4.2
Clark	2.43	1.25	51.2	2.4	3.4
Lewis	2.90	1.38	47.6	1.2	4.0
LSD (0.05)	0.26	0.11	2.3	0.7	0.8
Italian cultivars (single trees)					
Tonda di Giffoni	3.06	1.44	47.2	2.0	2.5
Tonda G. d. Langhe	2.48	1.17	47.1	3.3	3.0
Tonda Romana	3.09	1.50	48.6	2.8	5.5

^zMean mass of a nut in grams.

^yMean mass of a kernel in grams.

^xRatio of kernel weight to nut weight.

^wFiber on the kernel pellicle was rated from 1 = none to 4 = much (Thompson et al., 1978).

^vEase of pellicle removal with dry heat (blanching) was rated from 1 = complete pellicle removal to 7 = no pellicle removal (Thompson et al., 1978).

LSD = least significant difference.

Table 3. Frequency of good nuts and seven types of defects in Sacajawea, three standard cultivars, and two selections in a replicated yield trial planted in 1999.

Selection	Good ^z	Blanks	Brown stain	Moldy kernels	Shriveled kernels	Poorly filled	Doubles	Black tips
OSU 228.084	83.3	7.3	0.4	1.4	1.4	5.8	0.1	0.4
Sacajawea	86.9	5.0	0.1	2.6	1.1	3.5	0.2	0.8
OSU 553.090	87.4	2.9	0.3	1.1	0.2	8.3	0.2	0.0
Barcelona	60.9	10.6	0.6	2.4	4.4	18.9	2.6	0.2
Clark	77.3	3.5	1.1	4.3	2.3	10.9	0.3	0.7
Lewis	75.9	2.8	0.3	7.4	0.8	11.8	0.8	1.1
LSD (0.05)	8.7	4.8	1.8	3.8	3.1	7.2	1.6	2.1
Italian cultivars (single trees)								
Tonda di Giffoni	48.0	14.3	1.0	26.8	1.3	11.8	0.0	0.5
Tonda G. d. Langhe	72.3	14.0	5.0	2.3	0.8	5.5	0.0	0.5
Tonda Romana	68.5	10.0	0.3	3.3	4.0	11.5	0.5	2.8

^zPercentages are from two 50-nut samples per tree for the 4-year period 2002 to 2005. Column headings are percentages of good nuts, blanks (nuts lacking kernels), nuts with brown stain disorder, moldy kernels, shriveled kernels, poorly filled nuts, doubles (two kernels in a nut), and kernels with black tips (usually associated with a split suture).

LSD = least significant difference.

incompatible on female inflorescences of 'Sacajawea'.

Two tests have shown 'Sacajawea' to have a high level of quantitative resistance to eastern filbert blight (EFB) (Table 4)

caused by the pyrenomycete *Anisogramma anomala*. A set of potted trees was grown in a lathhouse in 2000 and placed under a structure topped with diseased wood in the spring of 2001 as described by Pinkerton et al.

(1993). A second set was exposed in 2002. Cankers were counted and measured ≈ 20 months after exposure to EFB and the amount of disease expressed as total canker length per tree. A square root transformation was used to make the variances more similar. Control cultivars were included: 'Daviana' (highly susceptible), 'Barcelona' (intermediate), 'Lewis' or 'Hall's Giant' (moderately resistant), and 'Tonda di Giffoni' (highly resistant). Both tests showed that 'Sacajawea' has a level of quantitative resistance comparable to 'Tonda di Giffoni'. 'Sacajawea' does not have the complete resistance of 'Santiam' (OSU 509.064) and is not recommended for areas with high disease pressure. Pruning to remove cankers and fungicide applications are currently used to manage the disease in orchards of 'Barcelona' and other susceptible cultivars and are appropriate for 'Sacajawea' orchards.

Susceptibility to bacterial blight caused by *Xanthomonas campestris* pv. *corylina* has not been determined, although no trees have been lost to the disease in our trial plots.

Susceptibility to big bud mite (primarily *Phytoptus avellanae* Nal.) was rated in the replicated trial in Dec. 2002, 2003, and 2005. The scale was from 1 (no blasted buds) to 5 (many blasted buds). The average ratings indicate a high level of resistance for 'Sacajawea' (1.1) and 'Barcelona' (1.0), moderate resistance for 'Lewis' (2.3), and an intermediate response for 'Clark' (3.0). Blasted buds are very rare on 'Sacajawea', so chemical applications should not be necessary to control bud mite.

Some Oregon handlers offer premiums for early delivery and high kernel percentage. 'Sacajawea' would qualify for both premiums. Handlers may choose to offer additional incentives because of the excellent kernel quality of 'Sacajawea'. Three Italian cultivars command a premium price on the world kernel market because of their kernel quality, and a single tree of each was included in the trial. 'Tonda Gentile delle Langhe' from Piemonte in northern Italy commands a 50% premium but is highly susceptible to bud mites and EFB, and nut yields are low. 'Tonda Romana' from Lazio in central Italy commands a 25% premium. Its nuts are similar to small 'Barcelona' nuts and yield efficiency is similar, but kernels blanch poorly and trees are highly susceptible to EFB. 'Tonda di Giffoni' from Campania in southern Italy commands a 25% premium. Its trees yield well and have very good quantitative resistance to EFB, but kernel mold is a very serious problem. In 2005, 41% of the kernels of 'Tonda di Giffoni' were moldy in contrast to only 3.3% for 'Sacajawea'. 'Sacajawea' has kernel quality that merits a premium price but lacks the deficiencies of these three standard Italian cultivars.

Some year-to-year variation in the ease of rooting and abundance of roots has been noted. Rooted layers are slightly less vigorous and smaller in height and caliper than those of 'Barcelona'. Scions of 'Sacajawea' were distributed to nurseries in Jan. 2005 to

Table 4. Results of exposing potted hazelnut trees to eastern filbert blight in 2001 and 2002.

Exposure	Selection	No. of trees exposed	No. of trees infected	Canker length	Parentage
Spring 2001 ^z	Daviana	12	12	15.04	
	Hall's Giant	12	12	11.60	
	Willamette	12	12	9.72	
	OSU 468.029	12	11	9.14	Casina × Mortarella
	OSU 539.044	12	12	7.72	OSU 275.031 × Sant Pere
	OSU 577.060	12	12	6.96	T. di Giffoni × Clark
	OSU 614.060	12	12	6.82	Camponica × Clark
	OSU 574.056	12	12	6.35	Willamette × OSU 54.060
	Sacajawea	11	9	6.25	OSU 43.091 × Sant Pere
	OSU 539.031	12	11	6.04	OSU 275.031 × Sant Pere
	Tonda di Giffoni	11	10	5.10	
	LSD (0.05)	—	—	1.85	
Spring 2002	Daviana	12	12	12.46	
	Willamette	7	7	7.95	
	Lewis	12	11	6.38	
	Barcelona ^y	6	6	6.14	
	OSU 666.064	12	11	4.95	OSU 342.019 × Mortarella
	OSU 645.003	11	9	4.90	OSU 245.098 × Mortarella
	Sacajawea	12	5	2.69	OSU 43.091 × Sant Pere
	Tonda di Giffoni	12	9	2.57	
	LSD (0.05)	—	—	1.78	

^zSixty-six genotypes were exposed in both trials. Cankers were measured in December, ≈20 months after exposure. Least squares means were calculated for square root of total canker length per tree. Number of potted trees exposed, number infected, and parentage are also shown.

^ySix Barcelona trees died after the 2002 exposure from causes other than eastern filbert blight.

LSD = least significant difference.

allow propagation of trees in preparation for its release. Tissue cultures were established at OSU (W. Proebsting and L. Meneghelli) in

June 2005, and micropropagation is now being practiced on a commercial scale by private companies.

‘Sacajawea’ was released as a public cultivar and may be propagated without restriction. A list of Oregon hazelnut nurseries and micropropagators, and small quantities of scion wood, are available from the senior author (SM).

Literature Cited

- Manzo, P. and G. Tamponi. 1982. Monografia di cultivar di nocciuolo [in Italian]. Istituto Sperimentale per la Frutticoltura, Rome.
- Mehlenbacher, S.A. 1997a. Revised dominance hierarchy for S-alleles in *Corylus avellana* L. Theor. Appl. Genet. 94:360–366.
- Mehlenbacher, S.A. 1997b. Testing compatibility of hazelnut crosses using fluorescence microscopy. Acta Hort. 445:167–171.
- Mehlenbacher, S.A. and D.C. Smith. 1991. Partial self-compatibility in ‘Tombul’ and ‘Montebello’ hazelnut. Euphytica 56:231–236.
- Pinkerton, J.N., K.B. Johnson, S.A. Mehlenbacher, and J.W. Pscheidt. 1993. Susceptibility of European hazelnut clones to eastern filbert blight. Plant Dis. 77:261–266.
- Tasias-Valls, J. 1975. El avellano en la provincia de Tarragona [in Spanish]. Excma. Diputación Provincial de Tarragona, Fundación Servicio Agropecuario Provincial, Tarragona, Spain.
- Thompson, M.M., P. Romisondo, E. Germain, R. Vidal-Barraquer, and J. Tasias-Valls. 1978. An evaluation system for filberts (*Corylus avellana* L.). HortScience 13:514–517.