Inheritance of the Cutleaf Trait in Hazelnut

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Abstract. The cutleaf hazelnut [*Corylus avellana* L. f. *heterophylla* (Loud.) Rehder] is grown as an ornamental for its distinct leaf shape. Its leaves are slightly smaller, more deeply lobed, and more sharply toothed than those of standard hazelnut cultivars. When the cutleaf hazelnut was crossed with cultivars with normal leaves, all seedlings had normal leaves. When seedlings were backcrossed to their cutleaf parent, half of the seedlings expressed the cutleaf trait, and when crossed with each other in pairs, 25% of the seedlings were cutleaf. These segregation ratios indicate that the cutleaf trait is conferred by a single recessive gene for which the symbol *cf* is proposed. Progenies segregating simultaneously for leaf shape and color indicate that the cutleaf locus is independent of the locus controlling red leaf color and of the locus controlling a chlorophyll deficiency, which appears to be identical to that previously observed in seedlings of 'Barcelona'.

The cutleaf hazelnut is an ornamental form with unusual leaf morphology (Fig. 1). Compared to those of standard European hazelnut cultivars, its leaves are slightly smaller, more deeply lobed, and more sharply toothed. The form appears to be represented by a single clone that was first described as *Corylus urticifolia* by Noisette in 1825 (Rehder, 1949) and was mentioned by Goeschke (1887). The currently accepted scientific name is *Corylus avellana* L. f. *heterophylla* (Loud.) Rehder, although many synonyms can be found in the taxonomic literature. These synonyms include *C. avellana laciniata* (Döll) Petzold et Kirschner, *C. avellana urticifolia* (Hort.) A.DC., *C. avellana quercifolia* Booth Cat. ex Kirchner, and *C. avellana* var. *incisa pinnatifida* Hort. ex Winkler (Kasapligil, 1972; Rehder, 1949). Although the form name *heterophylla* is preferred today, it is an unfortunate choice, as it leads to confusion with the Asian shrub species *C. heterophylla* Fischer, which has a very different origin and appearance. To avoid possible confusion, we use the term cutleaf hazelnut in this paper, and we demonstrate that the leaf shape of this form is conferred by a single recessive gene.

Materials and Methods

Inheritance studies in hazelnut are complicated by the sporophytic incompatibility system that prevents self-pollination as well as many backcross and sib matings (Thompson, 1979). In addition, the cutleaf hazelnut is highly susceptible to big bud mite (primarily *Phytoptus avellanae* Nal.), has a strong ten-

dency to crop only in alternate years, and for all practical purposes, it is male-sterile and thus can be used only as a female parent in

Fig. 1. Leaves of cutleaf hazelnut seedlings (left and right) and a normal sibling (center).

Table 1. Segregation for leaf shape in hazelnut crosses.

Parentage ^z	No. plants		Expected	χ^2	P
	Normal	Cutleaf			
Cutleaf x Contorta	65	0			
Cutleaf x P. Rouge	56	0			
Cutleaf x Redleaf #3	61	0			
Cutleaf x VR 6-28	66	0			
Cutleaf x Aurea	7	0			
Cutleaf x Pendula	81	0			
Cutleaf x 30.013	12	0			
Cutleaf open-pollinated (o.p.)	102	0			
Cutleaf x 367.052	51	43	1:1	0.68	0.4–0.5
Cutleaf x 367.063	38	48	1:1	1.16	0.2–0.3
Pooled (two progenies)	89	91	1:1	0.02	0.8–0.9
Heterogeneity				1.82	0.1–0.2
367.045 x 367.071	61	27	3:1	1.51	0.2–0.3
367.049 x 367.045	10	5	3:1	0.56	0.4–0.5
367.049 x 367.063	110	43	3:1	0.79	0.3–0.4
367.052 x 367.045	168	61	3:1	0.33	0.5–0.6
367.057 x 367.052	186	57	3:1	0.31	0.5–0.6
367.065 x 367.076	89	34	3:1	0.46	0.4–0.5
Pooled (six progenies)	624	227	3:1	1.27	0.5–0.6
Heterogeneity				2.02	0.8–0.9

^zParentage of selections is as follows: 'Redleaf #3' is 'Barcelona' o.p.; VR 6-28 is 'Riccica di Talanico' x 'Gasaway'; 30.013 is 'Goodpasture' x 'Compton'. All selections whose first three digits are 367 are from open-pollination of the cutleaf hazelnut.

crosses. Blank nuts are very common; in Oregon, about half of its nuts are blank and similar observations have been made in France (Bergougnoux et al., 1978). Also, seeds of the cutleaf hazelnut are prone to decay when stratified or when treated with gibberellic acid to break dormancy. Nevertheless, persistent efforts resulted in several hundred seedlings and clear segregation ratios.

In 1986, open-pollinated seeds were harvested from two trees of the cutleaf hazelnut, stratified at 4C for 3 to 4 months, and planted as they sprouted. Seeds that had not germinated after 4 months in stratification were soaked for 24 h in gibberellic acid at 25 mg-liter⁻¹ to break dormancy.

Segregating progenies were produced from controlled crosses in Winter 1993. Hybrid seeds were harvested in mid-August and either stratified or soaked in 50 mg gibberellic acid/liter for 48 h to break dormancy. Sprouting seeds were planted in flats in the greenhouse, and leaf shape was scored $\approx$ 6 weeks later when the seedlings were $\approx$ 25 cm tall. Although cutleaf seedlings vary in leaf size, depth of lobes, and degree of serration, they are clearly distinguishable from their siblings with normal leaf shape (Fig. 1).

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Table 2. Simultaneous segregation for leaf shape and color in hazelnut crosses.

Parentage ^w	No. plants				1 Red : 1 green		3:3:1:1 ^z		3 Green : 1 yellow		9:3:3:1 ^y		Independence ^x	
	Normal		Cutleaf		χ^2	<i>P</i>	χ^2	<i>P</i>	χ^2	<i>P</i>	χ^2	<i>P</i>	χ^2	<i>P</i>
	Red	Green	Red	Green										
367.045 x 367.071	33	28	12	15	2.05	0.8–0.9	2.30	0.5–0.6					0.70	0.40
367.065 x 367.076	50	39	16	18	0.66	0.4–0.5	1.90	0.5–0.6					0.82	0.3–0.4
Pooled	83	67	28	33	0.57	0.4–0.5	3.81	0.2–0.3					1.55	0.2–0.3
Heterogeneity					0.82	0.3–0.4	0.39	0.5–0.6						
	Green	Yellow	Green	Yellow										
367.049 x 367.063	86	24	31	12					0.18	0.6–0.7	1.57	0.6–0.7	0.64	0.4–0.5

^zExpected ratio: 3 normal red : 3 normal green : 1 cutleaf red : 1 cutleaf green.

^yExpected ratio: 9 green normal : 3 yellow normal : 3 green cutleaf : 1 yellow cutleaf.

^xContingency test for independence.

^wAll selections whose first three digits are 367 are from open-pollination of the cutleaf hazelnut.

Chi-square goodness-of-fit tests were performed for an expected ratio of 1 normal : 1 cutleaf for backcross progenies, and 3 normal : 1 cutleaf for crosses between seedlings of the cutleaf hazelnut. Progenies segregating simultaneously for red leaf color and leaf shape were tested separately for each trait and for a combined ratio of 3 normal red : 3 normal green : 1 cutleaf red : 1 cutleaf green. One progeny segregating for leaf shape and a chlorophyll deficiency was tested separately for each trait and for goodness-of-fit to a combined ratio of 9 normal green : 3 normal yellow : 3 cutleaf green : 1 cutleaf yellow. Contingency chi-square tests were used to detect deviations from expectations based on independent assortment in the three progenies showing simultaneous segregation for leaf shape and color.

Results and Discussion

None of the 102 seedlings resulting from open-pollination of the self-incompatible cutleaf hazelnut displayed the cutleaf trait. Similarly, subsequent controlled crosses of the cutleaf hazelnut with seven different pollen parents with normal leaves resulted in 348 seedlings, none of which showed the trait (Table 1). However, a second generation of open-pollination produced a low frequency of cutleaf seedlings (13 of 276 seedlings in 1991 and 24 of 476 in 1992), indicating that the trait is recessive. These cutleaf seedlings presumably resulted from sib pollinations.

When first-generation seedlings were backcrossed to their cutleaf parent, about half of the resulting seedlings displayed the cutleaf trait and controlled pollinations among seedlings of the cutleaf hazelnut segregated 3 normal : 1 cutleaf (Table 1). These ratios indicate that this leaf form is conferred by a single recessive gene for which we propose the name *cutleaf* and the symbol *cf*. The two progenies segregating 1:1 were homogeneous, as were the six progenies segregating 3:1.

Three controlled crosses among seedlings of the cutleaf hazelnut segregated simultaneously for leaf shape and color (Table 2). Two progenies segregated for the presence of anthocyanin in the leaves, a trait controlled by a single dominant gene in *C. avellana* (Thompson, 1985) and one segregated for a recessive chlorophyll deficiency that appears to be identical to that observed by Mehlenbacher and Thompson (1991) in seedlings of 'Barcelona'. Several trees of 'Barcelona' were adjacent to the trees of the cutleaf hazelnut from which open-pollinated seeds were harvested, so it is likely that some seedlings were the result of cross-pollination with 'Barcelona'. Half of these seedlings would be expected to carry the recessive chlorophyll deficiency. Segregation ratios showed good fit to a 3:3:1:1 combined ratio for the two progenies segregating for red leaves, and to 3 normal : 1 cutleaf and 1 red : 1 green ratios for the individual traits. A contingency chi-square showed independence of the two traits, and the two progenies were homogeneous. The prog-

eny segregating for yellow leaves and the cutleaf trait showed good fit to a 9:3:3:1 ratio, and to a 3:1 ratio for each individual trait. A contingency chi-square showed independence of these two traits.

Control by a single recessive gene will facilitate combining this interesting leaf shape with traits other than leaf color, including contorted growth habit, and resistance to eastern filbert blight caused by *Anisogramma anomala* (Peck) E. Müller and big bud mite (*Phytoptus avellanae* Nal.).

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