

# Hazelnut Pollination

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ADDITIONAL INDEX WORDS. *Corylus avellana*, flowering, production, orchard management, filbert, alleles

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**SUMMARY.** Hazelnuts, (*Corylus avellana* L.), are wind-pollinated, monoecious, mostly dichogamous, and self-incompatible. About 90% of the cultivars studied are protandrous. Anthesis of the pistillate flower is temperature-dependent and occurs December through February, peaking in January. Stigmatic surfaces may remain receptive for up to 3 months. Four to 5 months separate pollination and fertilization of the ovule; the latter usually occurring between mid-May and the end of June in Oregon. A 10% pollinizer density has been the standard, with a recommended distance of 66 ft (20 m) or less between the main cultivar and the nearest pollinizer. Two or three different pollinizer cultivars, with different times of pollen shed, are recommended. The Oregon hazelnut industry is presently combating the fungal disease, eastern filbert blight, caused by *Anisogramma anomala* (Peck). Current management recommendations suggest reducing risk of infection are to reduce the most susceptible pollinizer cultivars to a density 5%, then gradually replace those left with immune or more resistant genotypes.

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**H**azelnut production in the U.S. is centered in Oregon's Willamette Valley. There are nearly 30,000 acres (12,141 ha) of hazelnuts in Oregon, representing about 5% of the world's production. Turkey produces around 70%, followed by Italy at 20%, with Spain and the U.S. contributing most of the remaining production.

Hazelnuts are wind-pollinated, with pollen transfer taking place in the winter months. They are monoecious, and self-incompatible (Thompson, 1979a). The incompatibility is controlled by a single locus with multiple alleles and is a sporophytic type (Thompson, 1979b). The S-alleles of several cultivars were listed by Thompson (1979c), and Mehlenbacher and Thompson (1988). The 25 unique S-alleles have been identified in *Corylus avellana* L. (Mehlenbacher, 1997a).

All alleles identified to date are codominant in the pistil. They exhibit either dominance or codominance in the pollen (Mehlenbacher and Thompson, 1988). Scanning electron microscopy confirmed the stigmatic surface as the site of incompatibility (Hampson et al., 1993). Incompatible pollinations are expressed as delayed or reduced germination, with distorted pollen tubes that fail to penetrate the stigma.

Mehlenbacher (1997b) used a fluorescence microscopy method to determine the compatibility of crosses within 24 h, using female flowers from bagged branches and frozen pollen.

Stigmatic surfaces remain receptive for up to 3 months (Thompson, 1979b). A.N. Azarenko is currently investigating the biochemical, physiological and molecular aspects of sporophytic self-incompatibility. Two RAPD markers have been identified for the S<sub>1</sub> and S<sub>2</sub> alleles (Pomper et al., 1998).

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**Table 1. Compatibility of selected hazelnut pollinizers and cultivars.**

Pollen Parent	Alleles expressed	Cultivar <sup>2</sup>														
		TG	W	VR11	B	L	VR20	Ca	Cl	VR23	HG	G	J	E	OSU	
Female parent		2 <sup>y</sup>	3	3	1	3,8	3	10,21	3	5,15	14	3	1	1		
TG	2 <sup>x</sup>	23	- <sup>w</sup>	+ <sup>v</sup> m <sup>u</sup>	+m	+m	+m	+l	+	+l	+	+l	+	+	+	+
B	1	2	-	+	+e	-	+m	+m	+l	+l	+l	+l	+	+	-	-
W	1	3	+e	-	-	-	-	-	+ml	-	-	+ml	+l	-	-	-
L (OSU243.002)	3	8	+e	-	-	+e	-	-	+ml	-	-	+ml	+ml	-	+	+
E	1	11	+	+	+	-	+e	+e	+m	+m	+m	+l	+l	+l	-	-
Ca	10	21	+	+	+	+	+	+	-	+m	+m	+m	+m	+	+	+
Cl (OSU276.142)	3	8	+	-	-	+	-	-	+	-	-	+e	+	-	+	+

<sup>2</sup>TG = 'Tonda di Giffoni', W = 'Willamette', VR11 = VR 11-27, B = 'Barcelona', L = 'Lewis', VR20 = VR 20-11, Ca = 'Casina', Cl = 'Clark', VR23 = VR23-18, HG = 'Hall's Giant', G = 'Gem', J = Jemtegaard #5, E = 'Ennis', OSU = OSU228.084.

<sup>y</sup>The horizontal row found below the list of cultivars has the incompatibility alleles that are expressed in the pollen listed.

<sup>x</sup>The (-) indicates an incompatible cross. It is preferable when identifying suitable pollinizers that the cross is compatible in both directions.

<sup>v</sup>A (+) indicates that the cross is compatible.

<sup>w</sup>The text found below the + indicates the time of pollen shed relative to the bloom of the female parent; m = mid, e = early, l = late.

<sup>u</sup>In the vertical column, to the right of the female parent column, is the list of incompatible alleles that are expressed in the female flower.

**Table 2. Compatibility of selected hazelnut pollinizers and cultivars.**

Pollen Parent	Alleles expressed	Cultivar													
		B	Ca	Cl	E	HG	J	L	TG	W	VR11	VR20	VR23	OSU	
Female parent		1 <sup>y</sup>	10,21	3,8	1	5,15	3	3,8	2	3	3	3	3	1	
G	2 <sup>x</sup>	14	+ <sup>x</sup>	+	+	+	+	+	- <sup>w</sup>	+	+	+	+	+	
TG	2	23	+	+	+	+	+	+	-	+	+	+	+	+	
HG	5	15	+	+	+	-	+	+	+	+	+	+	+	+	
J	2	3	+	+	-	+	-	-	-	-	-	-	-	+	
VR11	1	3	-	+	-	+	-	-	+	-	-	-	-	-	
VR20	2	3	+	+	-	+	-	-	-	-	-	-	-	+	
VR23	1	3	-	+	-	+	-	-	+	-	-	-	-	-	
OSU	1	2	-	+	+	-	+	+	-	+	+	+	+	-	

<sup>2</sup>TG = 'Tonda di Giffoni', W = 'Willamette', VR11 = VR 11-27, B = 'Barcelona', L = 'Lewis', VR20 = VR 20-11, Ca = 'Casina', Cl = 'Clark', VR23 = VR23-18, HG = 'Hall's Giant', J = Jemtegaard #5, E = 'Ennis', OSU = OSU228.084, G = 'Gem'.

<sup>y</sup>The horizontal row found below the list of cultivars has the incompatibility alleles that are expressed in the pollen listed.

<sup>x</sup>A (+) indicates that the cross is compatible.

<sup>w</sup>The (-) indicates an incompatible cross. It is preferable when identifying suitable pollinizers that the cross is compatible in both directions.

<sup>v</sup>In the vertical column, to the right of the female parent column, is the list of alleles that are expressed in the female flower.

Compatibility, the amount of viable pollen produced, and time of pollen shed must be considered when selecting a pollinizer. Diploid cultivars have two alleles: in a female flower both alleles are expressed and therefore they are codominant. The pollen may express one or both alleles, and are therefore dominant or codominant, respectively. If an allele expressed in the pollen meets the same allele in the female flower, then the cross is incompatible.

An example is a 'Barcelona' female flower with the S<sub>1</sub>S<sub>2</sub> alleles pollinated with 'Ennis'. The pollen expresses the S<sub>1</sub> allele. This cross is incompatible. Whereas, 'Barcelona' flowers pollinated with 'Hall's Giant' is compatible because the alleles expressed in the pollen are S<sub>5</sub> and S<sub>15</sub>. Table 1 summarizes the compatibility of a selected group of cultivars,

pollinizers and advanced selections.

There are cultivars that might be compatible, however they produce a high percentage of defective pollen. 'Tonda Gentile delle Langhe', S<sub>2</sub>S<sub>7</sub>, is compatible with 'Barcelona', 'Ennis', 'Casina', and 'Willamette', but generally produces a high percentage of nonviable pollen. Therefore, this cultivar is not recommended as a pollinizer.

Hazelnuts are mostly dichogamous. About 90% of the cultivars studied are protandrous. Pistillate flower anthesis is temperature dependent and occurs December through February, peaking in January. Four to five months separate pollination and ovule fertilization. Fertilization usually occurs between mid-May and the end of June in Oregon.

Pollinizer density recommendations around the world have ranged from 3% to 30%. In Oregon a 10%

pollinizer density has been the standard, with a recommended distance of less than 66 ft (20 m) between the main cultivar and the nearest pollinizer. Two or three different pollinizer varieties with different times of pollen shed are recommended (Tables 1-3).

European planting strategies usually have pollinizers placed at distances of about 60 ft or less from the furthest tree. Hazelnut recommendations are based on these earlier observations and use 50 to 70 ft (15.2 to 21.3 m) as the greatest distance from pollinizers.

The Oregon hazelnut industry is presently combating the fungal disease, eastern filbert blight (Johnson et al., 1996; Pinkerton et al., 1992). Current management recommendations suggest reducing the susceptible pollinizer cultivars to a density of 5%, and gradually replacing those left with immune or

more resistant genotypes. 'Barcelona' plantings with 'Daviana' pollinizers account for about 70% of Oregon's hazelnut acreage. 'Daviana' is highly suscep-

tible to eastern filbert blight infection. Figure 1 ranks the relative susceptibility of hazelnut cultivars used in Oregon.

In summary, eastern filbert blight

susceptibility as well as horticultural considerations of compatibility and bloom overlap with the main cultivars, is impacting pollinizer selection decisions in Oregon's hazelnut industry.

**Table 3. Hazelnut cultivar and pollinizer combinations for possible use in the in-shell and kernel markets. Incompatibility alleles noted in parentheses.**

Market	Cultivar	Pollinizer
In-shell	Barcelona (S <sub>1</sub> S <sub>2</sub> )	Hall's Giant (S <sub>5</sub> S <sub>15</sub> ) Gem (S <sub>2</sub> S <sub>14</sub> ) Lewis (S <sub>3</sub> S <sub>8</sub> ) VR4-31, VR11-27 (S <sub>1</sub> S <sub>3</sub> ) VR20-11 (S <sub>2</sub> S <sub>3</sub> )
	Ennis (S <sub>1</sub> S <sub>11</sub> )	Casina (S <sub>10</sub> S <sub>21</sub> ) Hall's Giant (S <sub>5</sub> S <sub>15</sub> ) Jemtegaard #5 (S <sub>2</sub> S <sub>3</sub> ) VR20-11 (S <sub>2</sub> S <sub>3</sub> ) VR23-18 (S <sub>1</sub> S <sub>3</sub> )
Kernel	Willamette (S <sub>1</sub> S <sub>3</sub> )	Tonda di Giffoni (S <sub>2</sub> S <sub>23</sub> ) Hall's Giant (S <sub>5</sub> S <sub>15</sub> ) Gem (S <sub>2</sub> S <sub>14</sub> )
	Lewis (S <sub>3</sub> S <sub>8</sub> )	Tonda di Giffoni (S <sub>2</sub> S <sub>23</sub> ) Barcelona (S <sub>1</sub> S <sub>2</sub> ) Hall's Giant (S <sub>5</sub> S <sub>15</sub> ) Gem (S <sub>2</sub> S <sub>14</sub> )
	Clark (S <sub>3</sub> S <sub>8</sub> )	Hall's Giant (S <sub>5</sub> S <sub>15</sub> ) Gem (S <sub>2</sub> S <sub>14</sub> ) Later pollinizer to be determined

**Fig. 1. Relative ranking of hazelnut cultivars to eastern filbert blight susceptibility based on observational field data (Pinkerton et al., 1993; personal communication, J.W. Pscheidt and S.A. Mehlenbacher).**

Susceptible	Intermediate	Resistant	Immune
Ennis (++++++)	Barcelona (++++)	Clark (++)	Gasaway (-)
Daviana (++++++)	Butler (++++)	Lewis (++)	VR4-31 (-)
DuChilly (++++++)	Hall's Giant (+++)	Gem (+)	VR11-27 (-)
TGdL (++++++)	Willamette (+++)	TdG (+)	VR20-11 (-)
Tonda Romana (++++++)			VR23-18 (-)
Casina (++++)			
Negret (++++)			
Newberg (++++++)			
Dundee (++++++)			

TGdL = 'Tonda Gentile delle Langhe'; TdG = 'Tonda di Giffoni'.

++++++ = Highly susceptible, long canker length, low vigor. Cultivar type = 'Ennis'.

++++ = Susceptible, long canker length, medium vigor.

+++ = Intermediate susceptibility, good vigor in the presence of eastern filbert blight. Cultivar type = 'Barcelona'.

++ = Intermediate susceptibility, but with shorter cankers or fewer stromata than 'Barcelona', good vigor in the presence of eastern filbert blight.

+ = Resistant, shorter cankers and with good vigor. Cultivar type = 'Clark'.

- = Highly resistant, shortest cankers, can become infected but only under very high disease pressure. Cultivar type = 'Tonda di Giffoni'.

- = Immune, does not become diseased. Cultivar type = 'Gasaway'.

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