Hazelnuts in Ontario — Biology and Potential Varieties

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Factsheet

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INTRODUCTION

This Factsheet discusses the global hazelnut industry and describes several challenges to growing hazelnuts that are unique to Canada and Ontario conditions, including hardiness of hazelnuts to cold winter and spring frost, resistance to Eastern filbert blight disease and requirements for pollination. A basic description of plant biology and growth characteristics of hazelnut leads into a more detailed description of each hazelnut variety. These hazelnut varieties may have potential as crop varieties, or as a source of pollen (pollinizers), to develop a profitable commercial hazelnut industry in Ontario.

FACTORS REQUIRED TO DEVELOP A HAZELNUT INDUSTRY IN ONTARIO

To establish a viable hazelnut industry in Ontario, there must be an established local, interprovincial and international market. In 2006, an international confectionary company built a new plant in Brantford, Ontario, as the centre of their North American operations. This plant initially used 6,000 metric tonnes of hazelnuts per year. It would take an estimated 5,000–6,000 ha (12,000–15,000 acres) of hazelnut trees to supply this and other markets.

At present, there are small local opportunities for selling fresh in-shell nuts, however, the need for other Canadian markets for both the in-shell and the kernel (processing) markets remains.

Two major factors limit the culture of hazelnuts in Ontario and eastern Canada: susceptibility to Eastern filbert blight (*Anisogramma anomala* (Peck, E. Müll.)) and a lack of cold hardiness. Growing hazelnuts successfully in Ontario requires varieties with blight resistance and winter hardiness, in particular, varieties with hardy catkins that are not killed by frost during bloom and varieties with a range of pollen shedding, for consistent yields.

Once blight-resistant and winter-hardy varieties have been identified, they will be evaluated for nut quality. This will enable suitable varieties to be selected for different markets, especially the processing market.

HAZELNUT PLANT

Species

Hazelnuts, filberts or cobnuts, are members of the genus *Corylus,* a member of the Birch family. There are about 15 species. Of these, five shrubs and four tree species are most commonly recognized and commercialized. Almost all widely used varieties were selected over many centuries from local wild populations of the European hazelnut, *C. avellana* L., in Europe and Turkey.

The European hazelnut is native throughout most of Europe (except some islands and in the extreme north and northeast), east to the Caucasus and Asia, south to North Africa and temperate western Asia. It grows and is cultivated in countries and regions where summer temperatures are comparatively cooler and winter temperatures uniform and mild. Winters with alternating freezing and thawing cause most damage to the trees.

In North America, European hazelnut varieties are not successful, mainly because they are very susceptible to Eastern filbert blight and all or parts of the plant are killed by the cold winters.

Two hazelnut species are indigenous to Ontario: *C. americana* Walt., the American hazelnut, and *C. cornuta* Walt., the beaked hazelnut. The American hazelnut grows from the St. Lawrence along Lake Ontario westward to Lake Huron (approximately the Carolinian zone) and in the Lake-of-the-Woods region near the Ontario–Minnesota border. This matches the major fruit-growing areas of Ontario. The beaked hazelnut grows throughout Ontario to about 50° N.

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Ontario

Table 1. Description of American, European and beaked hazelnut plants

Characteristics	American Hazelnut	European Hazelnut	Beaked Hazelnut
Growth habit and height	multi-stem shrub, 2–3 m tall	multi-stem shrub, 3–10 m, occasionally 15 m tall	multi-stem shrub, 3–4 m tall
Bark	smooth, grey	smooth, dark-brown	smooth, grey
Leaves	5–12 cm long and 2.5–7 cm wide, bright green on the upper surface and pale green on the lower surface, round or heart-shaped at the base and tapered point at the apex, margins sharply and irregularly serrated	5–10 cm long, rounded broad-ovate, hairy on both sides, margin doubly serrated	6–10 cm long, ovate or narrowly oval, serrulate margins, scattered hairs on the upper surface with sparse hairs on the lower surface
Catkins	up to 7 cm long	2–8 cm long, pendulous, grouped in clusters of 1 to 4	up to 5 cm long
Female flowers	tiny cluster with red stigma protruding from bud	5 mm long, tiny cluster with red stigma protruding from bud	tiny cluster with red stigma protruding from bud
Nuts	in clusters of 2 to 6, 1–1.5 cm long, hard shelled nuts, enclosed in husk	in clusters of 1 to 12 1.5–2 cm in diameter, enclosed in husk	up to 1.2 cm long, hard-shelled nuts, enclosed in husk, light brown
Husks	twice the length of the nuts, not constricted beyond the nut	can vary from one quarter to twice as long as nuts, flared out, tubular or constricted beyond the nut	flask-shaped involucres prolonged into a lacerate beak open at the end

Descriptions

The following section gives a generalized description of the plant habit, the flowers, nuts and the root system. Details of the three species found in North America are found in Table 1.

Longevity

Hazelnuts are perennial plants that produce an annual crop of nuts, however, they have a strong tendency to bear in alternate years. They often begin to bear within 3 years of planting (Figure 1), with larger yields after 5–6 years. Full production is usually reached in 8–10 years.

Figure 1. A four-year-old hazelnut orchard.

Growth Habit

The shape of the hazelnut tree is determined by branch angle, training and pruning of the young tree. The tree shape varies from very erect to very spreading or drooping. The single trunk and rounded, upright-spreading growth habit of 'Barcelona' have been considered desirable traits, since they facilitate mechanical harvesting. Some newly released varieties have a more spreading, open canopy ('Yamhill'), which requires some training and pruning to allow sunlight to penetrate the canopy and machinery to pass underneath. The tree density is determined by several factors, including internode length, number of lateral buds that grow, length of "blind" wood, degree of apical dominance and size of the leaves. Tree density ranges from very open to very dense. It is desirable to have moderately dense trees, which allow more sunlight to penetrate to facilitate nut set. The size of the tree is determined by the vigour of the annual growth. Trees with moderate vigour are preferable.

Flowers and Nut Development

Hazelnuts have both male and female flowers on the same plant. The male flowers (Figure 2) are borne in catkins that arise in the axils of basal leaves on the current season's stem. A small protective bract subtends each individual male flower, and 150–200 male flowers on a single stem form the catkin. Catkins develop rapidly from August onwards, then remain dormant during the winter.

Figure 2. Male "catkin" flowers of hazelnut.

The female flowers (Figure 3) are borne in tight clusters at three locations: singly at the basal leaves on one-year wood, in groups of one to six on the catkin peduncles and on very short spurs on older wood. The flower buds are indistinguishable externally from vegetative buds until they open. Once the catkins start to open, four to 18 styles emerge at the top of the bud. At first, they appear like a small red dot and then continue to elongate and reflex. The stigmas develop as epidermal papillae on the styles, which develop first at the apex, and then progressively downwards as the style elongates. Over 80% of the style length may be receptive. If unpollinated, stigmas may remain receptive up to 2 months. If the exposed parts of styles are damaged by frost, abrasion or are desiccated by wind, the lower-protected parts emerge as functional flower tissue.

Male and female flowers do not open together. Under Ontario conditions, female flowers bloom in early March, and the male flowers open approximately 10 days later. The pollen sheds within a few days after the catkins open.

Figure 3. Female hazelnut flower.

Hazelnut has a sporophytic self-incompatibility system governed by a single gene with multiple alleles (S alleles). Therefore, in an orchard, there must be at least two varieties, and to ensure that the combinations will cross-pollinate, growers must find varieties with different S alleles.

Pollen usually dehisces when the relative humidity drops. In still air, the dehisced pollen will drop on top of the bracts below and be held there until it is blown off by the wind. When they are open, the catkins lose their rigidity and flex readily in the wind, which releases the pollen. Once the female flowers have been pollinated, the exposed parts of the styles wither and turn black. Pollen tubes grow to the base of the style within 4–7 days. When it reaches the base of the style, the tip of the pollen tube, containing the sperm and vegetative nuclei, forms an irregular-shaped structure with callus walls and remains this way for a few months. During that time, the meristematic cells at the base of the styles begin to develop into a mature ovary. As the weather warms up in late spring, the pollen tube continues to grow into the ovary and fertilizes the egg.

For nuts to develop successfully, compatible pollination must take place. Without pollination, the flowers wither and fall. Blank nuts (developed to full size but lacking kernels) occur because compatible pollination has taken place but the embryo (seed) has failed to develop. After fertilization, the embryo grows for 5–6 weeks, and continues to differentiate for 2 more weeks.

When the nut has reached full size in July, the ovary wall begins to lignify to form a hard shell, hardening first at the apex and gradually progressing to the base of the nuts. In late August, the nuts start to change colour from the base upwards. At the same time, the nut begins to separate from the involucre as the cells at the base of the nut die. Once this separation is completed, the nut is ready to drop. As the involucre matures and dries, it gradually opens to release the nut. In Ontario, nuts usually fall for several weeks from early September to the end of October.

Root Growth

Hazelnut trees are shallow-rooted. Feeder roots are concentrated in the top 20 cm of the soil outwards from the trunk to beyond the spread of the limbs. Below this level, the feeder roots rapidly decrease, and below 90 cm, there are virtually none. Hazelnut trees have very few anchoring roots.

Almost all hazelnut varieties form suckers, but the amount depends on the variety.

Hardiness and Phenology

Cold winters have limited the culture of hazelnut in Ontario and eastern Canada. This is because low, freezing temperatures will injure or kill stem tissue, vegetative buds, female flower buds and catkins. In an Oregon study, vegetative buds in midwinter were as hardy as, or hardier than the cambium and most survived -40°C without injury. Catkins were hardier than female flowers in October, but the reverse was true in January. In January, the blooming female flower buds of 'Gasaway' and 'Hall's Giant' were uninjured at -40°C. The killing temperature for catkins in January ranged from -15°C for 'Tonda di Romana' to -35°C in 'Gasaway' (Hummer et al. 1986). Catkins are very tender during elongation. In Italy during March and April, the killing point was -12°C for most unopened buds, -3°C when the first leaf appeared, and -1°C at the 2-leaf or 3-leaf extended stage. 'Tonda di Romana' and 'Barcelona' were moderately sensitive to spring frost while 'Hall's Giant' and 'Daviana' were very resistant to spring frost (Tombesi & Cartichini, 1974).

For terminal buds to break in spring, they need to have completed dormancy or physiological rest and have had sufficient heat to grow. To complete dormancy, various tissues need 0°C to 7°C for varying times: 100–990 hours for catkins, 290–1,645 hours for pistillate flowers, and 365–1,550 hours for vegetative buds.

Varieties that leaf out early in the spring are subject to spring frost injury. Therefore, the time when terminal buds break must be considered. During the spring (in a field of one-year-old seedlings) at Simcoe, Ontario, on April 6, 2009, buds broke on 'Barcelona', 'Lewis', 'Clark' and 'Butler'. This was 2 weeks earlier than New York selections ('Grimo 186M' and 'Geneva'). The terminal buds of several varieties with European background selected by a grower in Courtland, Ontario, broke 11–13 days later than 'Barcelona'.

VARIETIES

Variety Selection

Because the hazelnut varieties currently grown worldwide have not been widely tested in Ontario, the choice of variety for Ontario growing conditions should be based on results from other areas, and on grower's direct experiences. Historically, hazelnut varieties planted in Ontario have been 'Grimo', 'Slate' and seedling plants. However, many of these trees have died of Eastern filbert blight.

When choosing a variety, consider the following factors:

- the intended market
- resistance to Eastern filbert blight
- winter hardiness of the wood and catkins
- the quality of the nuts

When nut quality and potential markets are considered, the first important nut characteristic is the shape of the nut. Large, round or oblong nuts are suitable in the fresh market, but round nuts that have a uniform size are preferred for whole-nut-manufactured products. This is because round nuts will roast more evenly than oblong nuts.

Any variety that is planted must have a suitable pollinizer planted nearby. This is because hazelnuts are self-incompatible, which means they require pollen from another compatible variety to produce nuts. As well as the pollinizer variety's compatibility, the time that pollen is shed is a factor. The variety should shed its pollen when the female flowers are receptive to pollen, and not during warmer periods in winter.

Table 2. Variety reaction to Eastern filbert blight[1]

Immune	Possibly Immune	Resistant	Highly Resistant	Intermediate Susceptible	Susceptible	Highly Susceptible
Delta	C-16	Clark	Sacajawea	Casina	Barcelona	Butler
Epsilon	C-28	Gem	Tonda di Giffoni	Hall's Giant	Daviana	Tonda Gentile delle Langhe
Gamma	C-409	Lewis		Willamette	Ennis	Tonda di Romana
Geneva	G-19	Mortarella			Jemtegaard 5	
Jefferson	Grimo 186M	Skinner			Negret	
Santiam						
Slate						
Theta						
Zeta						

[1] Highly susceptible: long canker length, low vigor; Intermediate susceptibility: good vigor, shorter cankers; Susceptible: long canker length, medium vigor; Highly resistant: shorter cankers, infected under very high disease pressure; Resistant: shorter cankers, good vigor Immune — does not become diseased; Possibly immune: incomplete information.

Pollinizers should be good nut producers to contribute to the total crop yield. While this information is known for pollinizers grown in temperate regions of the world, it is not known how the pollinizer varieties will react in a climate like Ontario's, where the flowering season is very short.

Hazelnut varieties selected in Ontario will change over time with the results of research and grower experience. At present, many varieties are being tested in Ontario, including selections from Ontario, and as more information is obtained, a list of recommended varieties will be published.

The tables on this page summarize the known resistance to Eastern filbert blight (Table 2) and compatibilities of different varieties (Table 3), based on results from locations outside Ontario.

To decide which crop and pollinizer varieties to buy and what planting design to use in the orchard, consult these tables, the variety descriptions below, a supplier, experienced growers or an OMAFRA specialist.

Table 3. Hazelnut compatibility chart

				Pollen (Male) Parent															
				Barcelona	**Butler**	**Clark**	**Delta**	**Gamma**	**Hall's Giant**	**Epsilon**	**Jefferson**	**Jemtegaard 5**	**Lewis**	**Sacajawea**	**Santiam**	**Tonda di Giffoni**	**Theta**	**Yamhill**
		Alleles				3	1	10	5				3				5	
		Expressed*		1	3	8	15	10	15	1	3	3	8	1	3	2	15	8
Female Parent	**Barcelona**	1	2	–	+	+	–	+	+	–	+	+	+	–	+	–	+	+
	Butler	2	3	+	–	–	+	+	+	+	–	–	–	+	–	–	+	+
	Clark	3	8	+	–	–	+	+	+	+	–	–	–	+	–	+	+	–
	Delta	1	15	–	+	+	–	+	+	–	+	+	+	–	+	+	+	+
	Gamma	2	10	+	+	+	+	–	+	+	+	+	+	+	+	–	+	+
	Hall's Giant	5	15	+	+	+	–	+	–	+	+	+	+	+	+	+	–	+
	Epsilon	1	4	–	+	+	–	+	+	–	+	+	+	–	+	+	+	+
	Jefferson	1	3	–	–	–	–	+	+	–	–	–	–	–	–	+	+	+
	Jemtegaard 5	2	3	+	–	–	+	+	+	+	–	–	–	+	–	–	+	+
	Lewis	3	8	+	–	–	+	+	+	+	–	–	–	+	–	+	+	–
	Sacajawea	1	22	–	+	+	–	+	+	–	+	+	+	–	+	+	+	+
	Santiam	3	15	+	–	–	–	+	–	+	–	–	–	+	–	+	–	+
	Tonda di Giffoni	2	23	+	+	+	+	+	+	+	+	+	+	+	+	–	+	+
	Theta	5	15	+	+	+	–	+	–	+	+	+	+	+	+	+	–	+
	Yamhill	8	26	+	+	–	+	+	+	+	+	+	–	+	+	+	+	–

+ = compatible

– = incompatible

* = both alleles are always expressed in the female flowers but not necessarily in the pollen. Cultivars having the same numbers are incompatible for cross pollination. Those having different numbers are compatible for cross pollination.

Adapted from S.A. Mehlenbacher and A.N. Miller, Pollinizer Management in a Hazelnut Orchard, Oregon State University (1988).

Variety Descriptions

Note: The following variety descriptions are based on research or observations from other locations and may not be applicable to Ontario conditions. Use this information as a guide only.

'Barcelona' Introduced from Europe in 1885; standard for the U.S. hazelnut industry for the past century. Nuts are large (3.0–4.1 g), round, well-filled, brown and suitable for the in-shell market. 'Barcelona' produces many blank nuts (up to 13%), is moderately productive in the east and bears annually. Kernel percentage (the ratio of dried kernel weight to dried in-shell nut weight) is 43%. Kernel quality is very good with good flavour but very fibrous and of mediocre attractiveness. Approximately 50% of pellicles (skin surrounding the kernel) can be removed by dry heat. It ripens mid-season, and the nuts drop free from the husk. The husk is 50% longer than the nut. 'Barcelona' has intermediate susceptibility to Eastern filbert blight and is highly resistant to big bud mite.

'Butler' Originated as a seedling tree in the orchard of Joseph C. Butler of Wilsonville, Oregon. The variety was introduced in 1980 as a pollinizer to replace 'Daviana'. It was primarily selected for its high-yielding capacity and pollen compatibility with 'Barcelona'.

Pollen shed covers the latter half of the 'Barcelona' blooming. The large catkins are numerous and produce substantial amounts of viable pollen. Plant 'Butler' pollinizer trees at the ratio of 1:17 crop trees with a planting pattern of every sixth tree in every third row.

'Butler' nuts occur mostly in clusters of two or three and are free husking. Nuts are slightly longer than their diameter and fairly uniform. The shell is medium brown and striped with a moderate pubescence at the apical end. Kernel percentage by weight ranges from 45%–47%. 'Butler' has 16%–20% blanks, with some reports as high as 30%.

Nuts drop over a long period of time, starting just before 'Barcelona' drops. In Corvallis, Oregon, about 70% of crop is down by mid-September, but it may take up to 3 weeks for the remaining 30% to drop. 'Butler' is moderately susceptible to big bud mite and susceptible to Eastern filbert blight and bacterial blight.

'Clark' Released by Oregon State University in 1999. Average nut weight ranges from 1.7–2.8 g, while kernel weight ranges from 0.8–1.4 g. It has 5% blank and brown-stained nuts. The kernel quality is very good, with good flavour, texture, round shape and will almost completely blanch. Due to its kernel quality, size and shape, 'Clark' is very suitable for the processing industry.

Female flowers bloom very late. Newly released varieties 'Epsilon' and 'Zeta' with late pollen shed are very suitable pollinizers. Harvest is 7–10 days earlier than 'Barcelona'. Nut clusters contain 3–4 nuts and are free-husking. Yield is estimated at about 7 kg/tree in a high-cropping and 3 kg/tree in a light-cropping year. A strong biennial bearing pattern has been observed. Has good quantitative resistance to Eastern filbert blight and intermediate resistance to big bud mite.

'Epsilon' Released by Oregon State University in 2002. Average nut weight is 2.6 g. Kernel percentage by weight is 49%, and it blanches poorly. 'Epsilon' has 7% blank and brown-stained nuts. The frequency of mouldy kernels has averaged 8%, which would be excessive for a main crop variety but should not be a problem for a pollinizer. The trees set many catkins, and abundant pollen is shed late in the season, after 'Hall's Giant'. It is a suitable pollinizer for 'Clark'. The duration of pollen shed is intermediate to long. Immune to Eastern filbert blight and highly resistant to big bud mite.

'Gamma' Released by Oregon State University in 2002. Released as a pollinizer but also suitable as a main variety. The trees set many catkins, and pollen is shed in mid-season. The pollen shedding is short, therefore 'Gamma' should not be the sole pollinizer in an orchard. It is a suitable pollinizer for 'Lewis' and 'Barcelona', but sheds pollen too early for 'Clark'. The average nut weight is about 2.5 g, and it blanches poorly. Kernel percentage by weight is 52%. 'Gamma' has 12% blank and brown-stained nuts. The frequency of mouldy kernels is very low (1%). The variety is immune to Eastern filbert blight and resistant to big bud mite.

'Geneva' Developed in the breeding program at the New York Agricultural Experiment Station in Geneva, N.Y. A very productive, annual-bearing selection that produces a large spreading tree up to 4 m tall. Nuts are medium-to-large size, pointed and well filled. Nuts ripen in mid-season, and most drop free from the husk. Kernels are round with no clinging fibre. Immune to Eastern filbert blight and susceptible to big bud mite. Pollen compatibility with other varieties is unknown.

'Grimo 186M' Selected by Grimo Nut Nursery of Niagara-on-the-Lake, Ontario. The tree is large and moderately productive. The nuts are medium size, oval and well filled. The nuts ripen at the end of September, and most of them drop free from the husk. The kernels are oval with no clinging fiber. It is a moderately productive and alternate bearing variety. The variety is possibly immune to Eastern filbert blight and moderately resistant to big bud mite. The pollen compatibility with other varieties is unknown.

'Hall's Giant' Introduced to the U.S. about 1890 from Germany or Alsace. Large, brown, round-pointed nut, with thick shell. Average nut weight ranges from 3.3–4.5 g, while kernel weight ranges from 1.4–1.7 g. Its large nut size makes it very suitable for the in-shell market. Kernel percentage by weight ranges from 38%–44%. It has 5% blank and brown-stained nuts. The frequency of mouldy kernels is very low, about 0.6%. The pellicles were completely removed by dry heat. The variety matures a few days after 'Barcelona' and is a low-yielding variety. The husk is longer than the nuts. It is a late pollinizer. The variety is moderately resistant to Eastern filbert blight and highly resistant to big bud mite.

'Jefferson' Released by Oregon State University in 2009 for the in-shell market. The nuts of 'Jefferson' are large, well filled (3.2–4.2g) and have 45% kernels by weight. Raw kernels have a moderate-to-heavy amount of fibre on their pellicles. 'Jefferson' blanches only moderately well. Kernel quality is suitable for many end uses, although they are larger than desired by the chocolate and bakery industry. It has high yield, attractive nuts, kernels and good kernel quality. About 80% of the nuts fall free of the husk at maturity. The variety matures at or up to 3 days later than 'Barcelona'. 'Jefferson' has a low frequency of mouldy kernels. Pollen is shed in mid-season, but female receptivity is very late. Pollinizers that shed pollen very late are needed. In Oregon, one-third 'Eta' and two-thirds 'Theta' is suggested. 'Yamhill' pollen is effective on early emerging female flowers and should be incorporated into an orchard at double the normal planting density. 'Jefferson' is immune to Eastern filbert blight and resistant to big bud mite but is susceptible to bacterial blight.

'Jemtegaard 5' Selected by Olger Jemtegaard of Boring, Oregon. The selection was released in 1960. The nuts of 'Jemtegaard 5'are large, round-oval, with an average weight of 3.4 g. The variety has 45% of kernels by weight with very poor blanching ability. The flavor and texture are very good. It is a late-maturing variety, and most of the nuts drop free from the husk; the husk is slightly shorter than the nuts. The variety sheds pollen late in the season. 'Jemtegaard 5' is susceptible to Eastern filbert blight and moderately resistant to big bud mite.

'Lewis' Developed by Oregon State University, Corvallis, Oregon, and released in January 1997. The variety nut weight ranges from 2.7–3.0 g, while kernel weight ranges from 1.2–1.4 g. It has 6% blank and brown-stained nuts and up to 8% of mouldy kernels. The kernel quality is very good, with good flavour, texture, round shape with moderate blanching ability. Raw kernels have very little attached fibre. Nut clusters contain 3–4 nuts. Nuts are free husking and ready to harvest 5–7 days earlier than 'Barcelona'. 'Lewis' has not exhibited a biennial bearing habit.

Female flowers bloom at the same time as 'Barcelona'. Pollinizers suggested in Oregon are 'Tonda di Giffoni' and 'Hall's Giant'. Plant equal numbers of each pollinizer to pollinate the early- and late-appearing flowers. Has intermediate tolerance to Eastern filbert blight and is moderately susceptible to big bud mite.

'Santiam' Developed by Oregon State University, Corvallis, Oregon, and released in 2005. Nuts of 'Santiam' are suited for the kernel market, but are too small for the in-shell market. The nut weight ranges from 2.0–2.1 g, while kernel weight ranges from 1.0–1.1 g. Kernel percentage by weight ranges from 48%–52% with moderate blanching ability. 'Santiam' has less than 5% blank and brown-stained nuts with relatively few mouldy kernels at 4%. Nuts mature, and more than 90% fall free of the husk by the end of September. In most years, harvest of 'Santiam' was completed before the beginning of 'Barcelona' harvest. The variety has not shown a biennial bearing tendency.

'Santiam' sheds pollen early mid-season and has short-to-intermediate pollen shed. Female bloom occurs late-to-very late in the season, so it requires a very late-shedding pollinizer variety. 'Epsilon' and 'Zeta' are suggested in Oregon as late and very late pollen shedding varieties, respectively. 'Santiam' produces much pollen and has potential as a pollinizer. Rooting can be poor; young trees can die in the field.

Trees of 'Santiam' are immune to Eastern filbert blight and have intermediate resistant to big bud mite.

'Slate' Developed in the breeding program at the New York Agricultural Experiment Station in Geneva, N.Y. Nuts are medium-to-large, well-filled with thin and attractive shell colour. The nuts ripen in the mid-season, and most drop free of the husk. The kernels are firm and round, with no clinging fibre. This variety ripens a few days ahead of Geneva. 'Slate' is a good yielding, annual-bearing variety. The tree is medium size, somewhat compact, less than 3 m in height and produces few suckers. It is immune to Eastern filbert blight but susceptible to big bud mite. The pollen compatibility with other varieties is unknown.

'Tonda di Giffoni' Originated from Campania in southern Italy. Average nut weight is 3.06 g. Kernel percentage by weight is 47.2% with excellent blanching ability. Has over 15% blank and brown-stained nuts. The frequency of mouldy kernels is very large (in some years, over 41%). The variety commands a 25% premium because of the excellent kernel quality. Its trees yield well and have very good quantitative resistance to Eastern filbert blight.

'Theta' Released by Oregon State University in 2009 as a pollinizer variety. The nuts are small and almost round. Kernel quality is relatively good. The tree sets many catkins and sheds pollen very late in the season, a few days after 'Epsilon'. It is a very suitable pollinizer for 'Jefferson'.

'Yamhill' Released by Oregon State University in 2008 for the kernel market. Average nut weight is 2.3 g, while kernel weight is 1.1 g. Kernel percentage by weight is 49%; they blanch well, with few mouldy kernels. Raw kernels are attractive and have little fibre on their light brown pellicles. The nuts fall free of the husk at maturity; 'Yamhill' matures 10–14 days earlier than 'Barcelona'. 'Yamhill' nuts are borne in clusters of 4–5, in husks that are as long as the nuts. It is an early maturing and very productive variety.

'Yamhill' trees have average-to-high numbers of catkins that shed pollen early in the season. Female inflorescences emerge early in the season, therefore pollinizers that shed pollen in early to mid-season are suitable. In Oregon, the recognized pollinizers are one-third 'Gamma' and one-third 'Santiam' as early-shedding varieties and one-third of a mixture of late-shedding varieties including 'Delta', 'Epsilon', 'Zeta' and 'Jefferson'. Has complete resistance to Eastern filbert blight and is highly resistant to big bud mite.

'Zeta' Released by Oregon State University in 2002. Trees set a moderate number of catkins, which shed pollen later in the season, after Hall's Giant. A suitable pollinizer for 'Clark'. Average nut weight is 2.5 g. Kernel percentage by weight is 50%, with relatively poor blanching ability. 'Zeta' has 13% blank and brown-stained nuts. Frequency of mouldy kernels has averaged 0.5%. Nuts mature a few days before 'Barcelona' and have very good kernel quality. About 85% of the nuts fall free of the husk at maturity. Tree is vigorous, moderately productive, moderately resistant to big bud mite and immune to Eastern filbert blight.

'Delta' and **'Sacajawea'** are hazelnut varieties that are not suitable for growing in Ontario.

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