Searching for Resistance to Eastern Filbert Blight: Hazelnuts from the Republic of Georgia

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Hazelnuts are a favorite nut crop of many NNGA members. The plants are adapted to a wide range of climates and soils and their smaller stature makes them suitable for backyard orchards. They are easy to grow and harvest and require relatively little in terms of pesticides or other chemical inputs to produce tasty crops of nuts. Currently, there is renewed interest in growing them for personal consumption, as well as for large-scale production across much of the eastern U.S. and southern Canada. There are now hazelnut breeding programs located at Oregon State University (OSU) and Rutgers University, as well as hazelnut research underway at the University of Nebraska, Lincoln, Minnesota State University, the University of Guelph, and the Arbor Day Foundation.

The European hazelnut, *Corylus avellana*, is the most coveted of the *Corylus* genus because of its large, thin-shelled nuts. It is an economically valuable crop, ranking fifth in world tree nut production behind cashews (*Anacardium occidentale*), almonds (*Prunus dulcis*), walnuts (*Juglans regia*), and chestnuts (*Castanea* spp.). The top hazelnut producing country in the world is Turkey, which generally produces more than 70 percent of the world's crop (776,890 metric tons in 2007). Turkey is followed by Italy, which produces around 17-20 percent of the total, and then the U.S., which produces less than five percent. Other producing countries include Spain, Georgia, Azerbaijan, Iran, France, Greece, Russia and China (FaoStat, 2009).

As many NNGA members already know, a native fungal disease called Eastern Filbert Blight (EFB), caused by *Anisogramma anomala*, makes most European hazelnut cultivars nearly impossible to grow across much of North America, the only continent where this disease is found. The European hazelnut is very susceptible to EFB and the disease is blamed for why there has been no commercial production of hazelnuts in the eastern U.S. in the past. Conversely, commercial hazelnut production has thrived in the Pacific Northwest, as EFB was not found in this region until relatively recently and the moderate climate of the Willamette Valley is well suited to cultivars from Europe.

Our native American hazelnuts, *C. americana*, and its cousin the beaked hazel, *C. cornuta*, are very resistant to EFB, due to having evolved alongside the fungus that causes the disease over millennia. While the American species can be productive, their tiny, thick-shelled nuts do not compete with their European relative and for the most part have only been harvested from the wild for local consumption. *Corylus americana* can be found growing over a wide area of eastern North America, and because of its ability to harbor non-lethal EFB infections it acts as a reservoir of inoculum to infect European hazelnuts planted across its range. Fortunately, it also acts as a pool of genetic resources useful for breeding EFB resistant, cold-hardy hybrid hazels, as demonstrated by the early successes of J.F. Jones, G.H. Slate, C. Weschcke and others when crossing *C. americana* with cultivars of *C. avellana* (Crane *et al*., 1937; Weschcke, 1954; Slate, 1969; Rutter, 1987). However, when *C. americana* is used as a parent in breeding, it takes several generations (amounting to many decades) to recover EFB-resistant, cold-hardy hybrid plants with nut qualities and yields suitable for commercial production. For example, the early first generation hybrids developed by Slate, while suitable for backyard production, did not produce consistent yields of high-quality kernels in the amounts needed to support a commercially viable industry (Slate, 1961). Further generations of breeding were needed. While work to develop advanced generation *C. avellana* x *C. americana* hybrids continues at Oregon State University, Rutgers University and at several private nurseries, it will likely be a decade or more before a suitable proven hybrid cultivar is released to the public for commercial production.

One way to speed development of EFB resistant commercial quality hazelnuts is to search for resistance within the European species itself. While in general the species is highly susceptible, rare plants exist that are resistant to EFB, as demonstrated by the obsolete pollinizer *C. avellana* 'Gasaway'. While 'Gasaway' produces low yields of very tiny, poor quality nuts (making it a less than ideal parent in terms of nut characteristics), it was the first and only source of *C. avellana* resistance identified at a time when hazelnut production in Washington and Oregon was being devastated by EFB after its inadvertent introduction in the late 1960s. 'Gasaway' was shown to carry a dominant allele at a single locus that transmits EFB resistance to its progeny (Mehlenbacher and Thompson, 1991). Simply stated, 'Gasaway' transmits a gene for EFB resistance to fifty-percent of its offspring. Due to its predictable inheritance, a concerted effort was made at OSU to use 'Gasaway' and its offspring in controlled crosses to develop improved EFB resistant *C. avellana* cultivars. While EFB resistance was inherited in a simple manner, the poor nut quality of 'Gasaway' still required several generations of breeding, equating to over 30 years, to finally develop EFB resistant plants that produce high yields and kernels of proper quality for commercial markets. Nevertheless, the most recent OSU introductions ('Yamhill' for the kernel market and 'Jefferson' for the inshell market,) as well as several new compatible pollinizers, can be credited for revitalizing the hazelnut industry in Oregon. Currently, the acreage of hazelnut orchards in the Willamette Valley is increasing for the first time in decades. The power of systematic plant breeding is clearly visualized when comparing the poor nut quality of 'Gasaway' with that of the new excellent quality EFB resistant releases. This breeding success at OSU, besides saving the U.S. hazelnut industry, provides much tangible evidence to demonstrate the genetic improvement potential of *Corylus*, a genus that has undergone very little breeding and contains a great deal of genetic diversity. This evidence greatly bolsters enthusiasm to develop improved *C. avellana* and hybrid hazelnuts for colder regions across North America.

The identification of 'Gasaway' spurred the search for other resistant *C. avellana* cultivars and selections to provide a diversity of resistance genes to combat EFB. Shawn Mehlenbacher and his team at OSU closely evaluated much of the large *Corylus* germplasm collection at the USDA Clonal Germplasm Repository in Corvallis, Oregon, as well as their own diverse collections, for resistance to this disease. By developing and using both greenhouse and field inoculation techniques, they were successful in identifying a number of plants that did not succumb to EFB, with several representing improvements over 'Gasaway' in many respects (Coyne et al., 1998; Lunde et al., 2000; Chen et al., 2005 & 2007). They are currently using the best of these resistant plants in their breeding program to develop future releases for the Oregon hazelnut industry.

Following the successful approach of OSU, in 2002 a trip was made to southern Russia and the Crimean peninsula of Ukraine to collect hazelnut germplasm to search for additional sources of EFB resistance and other traits needed for breeding efforts in the U.S. This was the first time hazelnuts were collected from this region for evaluation on such a large scale. Nuts were collected from local markets and bazaars, road side stands, research stations and botanical gardens. Over 4,000 nuts were brought back to Rutgers, with a comparable group brought back to OSU. From this collection, over 1,200 seedlings were grown at Rutgers and inoculated with spores of *A. anomala*. In less than four years, a large majority of these plants quickly succumbed to the disease. However, after several more years of continued evaluation and constant disease pressure in the field, we were successful in identifying a small number that were highly resistant (Molnar et al., 2007). To our surprise, several of these plants produced large nuts of relatively high quality representing great improvement over those from 'Gasaway' (Fig. 1).

We are currently using our best resistant Russian plants in controlled crosses with pollen from elite but EFB susceptible hazelnuts from the OSU breeding program. Our goal is to concurrently investigate how the resistance genes are transmitted to the next generation while also working towards rapidly developing new resistant plants with much improved nut quality. This work was funded in part by a NNGA research grant. We hope that by identifying and using EFB resistant parents that have decent nut size and quality, crossed with parents having excellent nut quality from the OSU breeding program, we will produce improved EFB-resistant offspring in a shorter period of time compared to the work with 'Gasaway'. From our efforts, we now have over one thousand plants in the greenhouse and field representing the first generation of new hybrids from these Russian parents. We also have several thousand hybrid seeds in stratification from similar crosses made in 2009 that will be germinated and grown at Rutgers, as well as at OSU and the University of Nebraska, Lincoln.

Based on the success of the Russian collection, we recently initiated a new project to identify resistant plants from a different geographic location to add

Figure 1. Comparison of nut size of new EFB resistant Russian and Crimean hazelnut selections H3R13P40 and H3R14P26 with that of 'Gasaway'.

to our arsenal of EFB resistant germplasm with improved nut quality. In August 2009, an extensive collection of hazelnuts was made in the Republic of Georgia by Michele Pisetta with help from local expert Dr. Nana Mirotadze. Georgia is a small country approximately 70,000 sq. km in size (slightly smaller than South Carolina) that borders the Black Sea on the west, Russia on the north and east, and Turkey, Armenia, and Azerbaijan on the south (CIA, 2009). Over 4,000 seeds were collected from 62 different accessions, including local cultivars, selections, and wild plants from across the country representing a wide spectrum of the diversity present in the region (Table 1; Figure 2). The seeds were shipped under proper permits to the U.S. in October and are now undergoing stratification at Rutgers for germination in spring 2010. The resulting plants will be inoculated with spores of the EFB fungus in the greenhouse and will also be grown under severe disease pressure in the research fields at Rutgers, similar to the Russian and Crimean material described above. A large subset of this material will also be grown at OSU for evaluation in their breeding program.

Due to the high disease pressure at Rutgers, we expect over 95% of the plants to die from EFB in less than five years. Of the remaining plants, it is likely a small percent will express a high level of resistance to EFB. If we are able to grow a large number of plants (over 2,500), we hope to identify resistant selections that also produce high quality nuts. Only time will tell if our assumptions are correct. Once we identify the surviving plants we will evaluate them for nut characteristics (size, shape, kernel quality, kernel percent, etc.) and yield for several seasons. We will then propagate the best of these plants and grow them in multiple locations to assess how they perform under different climates and soils. We will also use them in controlled crosses with susceptible parents to evaluate if and how resistance is transmitted to their offspring. If we are lucky, we will identify new dominant genes for resistance in some of the plants that also produce decent quality nuts. We are hopeful that this will be the case, because most of the hazelnuts collected in Georgia were purposely selected from plants with above average to excellent nut quality, with many having round, well-filled kernels with a high ratio of kernel to shell.

Georgia holds a wealth and diversity of hazelnut germplasm that has only recently been available for evaluation in the west, with very little imported to the eastern U.S. prior to this study. This new project is a wonderful opportunity to not only find new EFB resistant germplasm, but also to learn about, connect with and possibly give back to the Republic of Georgia. For one, the best of the resistant plants identified here will be returned to Georgia to be held in a repository for use in breeding locally adapted EFB resistant plants, if it is ever necessary. Due to their wealth of genetic resources, rich soils and excellent climate, great opportunities exist in Georgia for increasing acreage and modernizing the production of hazelnuts. In this small country, which local legends indicate as the "Garden chosen by God for his own needs", Georgians are very fond of the hazelnut plant, which plays an important role as a secondary agricultural crop. However, the country's location next to Turkey, the largest world producer, it has not been easy for the Georgian hazelnut sector to establish itself as a leading entity in both quality and quantity.

In 2006, a survey on cropland was carried out by the Ministry of Agriculture indicating that out of the approximately 100,000 hectares dedicated to agriculture in the country about 15,000 were planted to hazelnut orchards. This figure has been increasing due to the extensive planting that followed the strong demand for hazelnuts in 2004; this dynamic originated due to an unexpected frost event that decimated Turkish production to a point where world demand could not entirely be matched by the decreased supply. Since then, many small-size orchards have been planted in Georgia, with the ma-

Table 1. Accessions of hazelnut seeds collected in the Republic of Georgia. Identification numbers correspond to placement on map in Fig. 2.

ID number	Region	Village	Cultivar name or description	Source
1	Adjara	Kopuleti	Berzula(Anakliuri)	roadside vendor
2	Adjara	Kopuleti	Gulshishvela	roadside vendor
3	Samegrelo	Zugdidi	Anakliuri	market
4	Adjara	Kopuleti	Dedopolis titi	private garden
5	Guria	Muhalistate	Skheniskbili	market
6	Abkhazia	Gali	Anakliuri	private garden
7	Adjara	Batumi	Dedopolis titi	market
8	Adjara	Kedo vaio	Giresum	market
9	Guria	Lanchuti	Cincia	market
10	Guria	Muhalistate	Kharistvala	market
11	Guria	Ozurgeti	Khasarula	private garden
12	Samegrelo	Daracheni	mixture of nuts	private garden
13	Imereti	Shorapani	5	private garden
14	Guria	Surebi	Shvelis Kura	private garden
15	Imereti	Vani	Nottingham	private garden
16	Imereti	Samtredia	Ganja(azj)	experimental garden
17	Imereti	Samtredia	KTN 30b (azj)	experimental garden
18	Imereti	Samtredia	Lewis	experimental garden
19	Imereti	Samtredia	Cosford	experimental garden
20	Kakheti	Lagodekhi	Ashera(azj)	market
21	Belakani(azj)	Belakani	Belakani	market
22	Belakani(azj)	Zakatala	Belakani	market
23	Kakheti	Gurjani-Kotechi	Kharistvala	roadside vendor
24	Kakheti	Gurjani-Bakuri	Chkvistava	private garden
25	Kakheti	Gurjani-Bakuri	Lombarda red and white	private garden
26	Kakheti	Gurjani-Bakuri	Anakliuri	roadside vendor
27	Kakheti	Telavi	Mekutkasheni	private garden
28	Kakheti	Pshaveli	Pshauri	private garden
29	Kakheti	Hikhalto	Hogi	private garden
30	Kakheti	Pshaveli	Shvelis Kura	private garden
31	Kakheti	Gurjani-Bakuri	Nemsa	roadside vendor
32	Kakheti	Pshaveli	Pshauri 2	private garden
33	Kakheti	Gurjani-Bakuri	Kachapura	market
34	Kakheti	Gurjani-Kotechi	AZJ Mix	market
35	Kakheti	Pshaveli	Pshauri 5	private garden
36	Belakani(azj)	Belakani	Gawasuria	market
37	Kakheti	Pshaveli	Hybrids	private garden
38	Kakheti	Pshaveli	Pshauri 3	private garden
39	Kakheti	Pshaveli	Unknown	private garden
40	Svaneti	Unknown	Wild	handpicked
41	Kakheti	Akhalsheni	Kerasuli	private garden

Table 1. continued

ID number	Region	Village	Cultivar name or description	Source
42	Raja	Orbeli-Lechkhumi	Pollinizers	private garden
43	Imereti	Zoureti	Zoureti 3	private garden
44	Imereti	Zoureti	Zoureti 4	private garden
45	Samegrelo	Zugdidi	Dedopolis titi	market
46	Imereti	Shorapani	Nemsa	private garden
47	Adjara	Chaqui	Kharistvala	market
48	Samegrelo	Senaki	mixture of nuts	market
49	Samegrelo	Marani	Dedopolis titi	private garden
50	Adjara	Kopuleti	Mshavala	roadside vendor
51	Kakheti	Bakurzi-Gurjani	Gulshishvela	private garden
52	Guria	Lanchuti	Anakliuri	market
53	Raja	Orbeli	Vanis tetri	private garden
54	Imereti	Zoureti	Zoureti 2	private garden
55	Raja	Gori	Cia	private garden
56	Imereti	Samtredia	Kx 29(azj)	market
57	Imereti	Samtredia	Willamette	experimental garden
58	Kakheti	Lagodekhi	*C. colurna*	woods
59	Imereti	Chiatura	Ata Baba	private garden
60	Samegrelo	Marani	Red Corylus	private garden
61	Imereti	Chiatura	Legimari	private garden
62	Imereti	Samtredia	Ganja(azj)	experimental garden

jority of them coming into full production between 2008 and 2012. Presently, the estimated hazelnut growing area in Georgia of 15,000 hectares is unequally divided among five production regions. Samegrelo is by far the most important of the regions, with over 10,000 estimated hectares and about 15,000 tons of production, while national production is over 25,000 tons. Guria, Imereti, Kakheti and Adjara follow with much less production, although cultivated areas are rapidly growing in each region, especially close to the Black Sea coast (Adjara) (Mirotadze, pers. com.) (Fig. 3).

Hazelnut is found growing at different altitudes across Georgia, from sea level up to 1600 meters in the mountains of the Little Caucasus. Most orchards are not irrigated, although this tendency could change in the region of Kakheti where droughts are becoming more frequent. The main problem related to water is flooding especially in the western part of the country where hazelnut often suffers root asphyxia during abundant precipitation in the fall season. Cultivation techniques are still primitive with a vast majority of farmers not using mineral fertilizers nor pruning the plants, which can produce an abundance of unproductive suckers (Fig. 4 and 5). Pollination is typically provided by the great number of wild hazelnuts that grow around cultivated orchards, although in recent years a need of pollinizers for the Samegrelo region has been assessed in order to solve problems related with over production of twin kernels and blanks.

The main cultivar in Georgia is ‘Anakliuri’, a round-shaped small nut that is believed to have originated in the area of Anaklia on the coast of Samegrelo region. This cultivar is considered to be moderately productive (1.5 tons/Ha) and while it grows similarly in habit to the Turkish cultivars on the Black Sea coast, its husks drop their nuts on maturity facilitating handpicking or eventually mechanized harvest. Although ‘Anakliuri’ has proved to be a reliable cultivar in terms of productivity and resistance to diseases, it carries some traits such as a early drop of catkins and intensive production of suckers that suggest it needs some genetic improvement to increase production. Other local cultivars are ‘Gulshishvela’, ‘Kachapura’, ‘Hogi’, ‘Dedopolis titi’, ‘Shveliskura’ and ‘Nemsa’ with the last being more suitable for the climatic

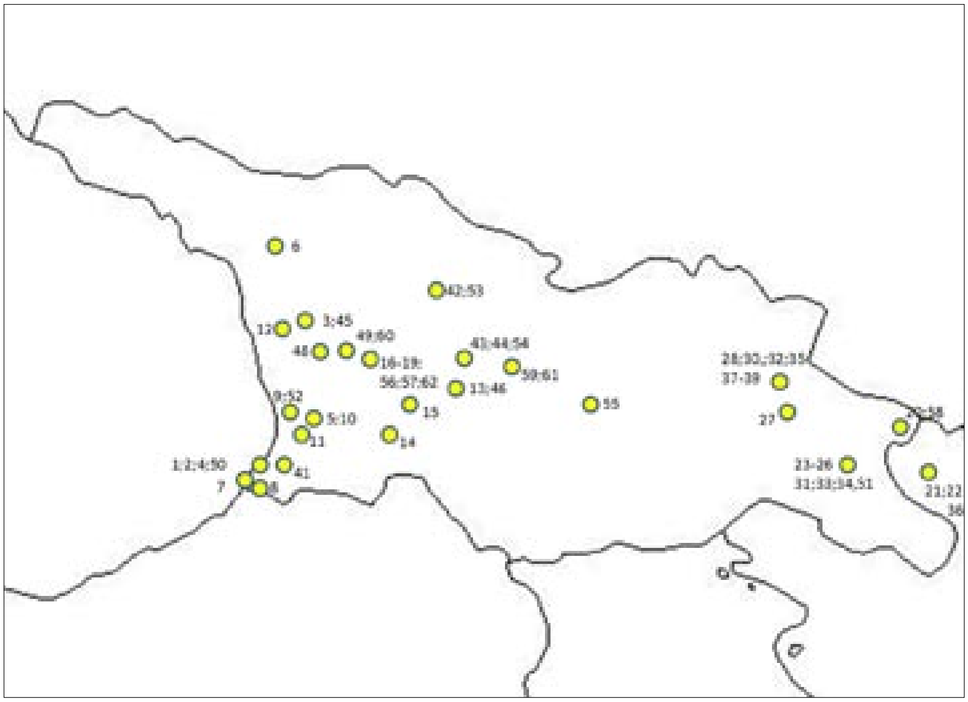

Figure 2. Collection locations of hazelnut accessions from Georgia corresponding to identification numbers in Table 1.

Figure 3. Map of the Republic of Georgia with corresponding regions.

conditions in the east of the country (Kakheti region) producing tiny, pointy nuts but withstanding a drier climate. Harvest is generally carried out by picking nuts from the ground by hand and drying them in open air under the sun. Unlike Turkey, no cases of aflatoxins have been reported for Georgian kernel exports. Many cracking facilities supplied with modern machinery arose in western Georgia during the last decade but a great number of them went out of business when Turkey recovered from the catastrophic 2004 harvest with outstanding crops in the last two seasons (2007-2008).

Georgia, like all the hazelnut-growing countries in Eurasia, has no presence of EFB. However, scientists recognize the danger of this pathogen and make efforts to exclude it from the country *via* strict quarantine efforts. As a precaution, we strive to identify local Georgian plants that are resistant to EFB for use in future genetic improvement efforts in the country should the disease be introduced. Other sources of infestation can be of significant immediate concern especially where not treated properly. Nationwide, filbert bud mite (*Phytoptus avellanae*) can be found thriving on any age of stand, while bacterial blights such as *Xanthomonas* spp. and *Pseudomonas* spp. are more common in the western side where conspicuous precipitation combine with acidic (pH less than 6) soils. Sudden summer outbreaks of fall webworm (*Hyphantria cunea*) are generally promptly treated by Georgian environmental protection services in order to preserve not only hazelnut, but all the susceptible tree species.

While current social and economic situations and governmental policies hinder opportunities for enhancing hazelnut production in Georgia, the country's wealth of high quality hazelnut genetic resources, fertile soils, excellent climate and hardworking great people set the stage for a bright future. It is our hope this study leads to the identification of new sources of EFB resistance coupled to plants that produce large yields of high-quality kernels. These new plants can provide a means to hasten the development of new cultivars suitable for colder areas of the world where EFB is present, while enhancing


Figures 4 and 5. Typical hazelnut orchards in Georgia.

the pool of resistance genes available to combat this devastating disease in the future. ❑

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