Hazelnut News

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Upper Midwest Hazelnut Development Initiative

10 Years and Counting!

- Jason Fischbach, UW-Extension Food and Energy Woody Crops Specialist

In November of 2007, the University of Minnesota convened a group of stakeholders and early-adopter growers to find ways to jump-start the hazelnut industry in the Upper Midwest. The meeting resulted in the Hazelnut Development Initiative Strategic Plan and the Upper Midwest Hazelnut Development Initiative (UMHDI) was born.

The 2007 Strategic Plan outlined 1, 5, and 10 year goals for:

1. Breeding and Propagation
2. Industry Infrastructure and Marketing
3. Agronomics and Production Systems
4. Harvesting and Processing Equipment.

When the UMHDI was launched in 2007, we had a staff of 0 and a budget of $0. Looking back, it's both amazing how much has been accomplished and humbling as to how much there is left to do. This special edition of *Hazelnut News* provides a 10-yr progress report on the completed and ongoing projects of the UMHDI.

Developing a new crop of any kind takes years, but developing a new woody crop is something entirely else due to the long breeding cycles of woody plants. The hard work and wait is worth it, however, given the enormous potential of hazelnut as both a high-value nut crop and a new conservation tool. Imagine what our agricultural landscape in the Upper Midwest might look like if instead of protecting soil and water quality *from* agriculture we had crops (like hazelnut) that allowed us to protect soil and water quality *with* agriculture. The potential of perennial crops is what gives all of us involved with hazelnuts the passion and fire to keep working everyday to make hazelnuts a reality.

I've been lucky enough to be involved with the UMHDI since the beginning and one of the highlights of my work has been working with growers. We wouldn't be where we are without growers willing to try new things and take a chance on a crop and industry that is still developing. The support, encouragement, and patience we've received over the years is greatly appreciated. I

As the UMHDI enters its second decade, grower involvement and support will become increasingly important. When we started in 2007, it was relatively easy to find grant funding, but most grant projects are 1-2 years and eventually funders move on to other new and exciting projects. It's a real challenge to keep funders excited, for example, for the 17 years it takes to develop a new cultivar. Going forward, it will be increasingly important for growers, processors, consumers, and stakeholders to raise their voices and convince Departments of Agriculture and the land grant Universities that hazelnuts are worth continued investment. In addition, the industry itself will have to find other ways and sources of funding to ensure research and development work continues. Exactly how this happens isn't yet known, but one of our goals for the next few years is to help build supply chain networks and grow the resource base in general to advance the industry.

To that end, we will be hosting a strategic planning and grower networking event this coming fall. This will be a chance for growers to guide the work of the UMHDI for another 10 years and help brainstorm ways to make sure there are sufficient resources to do the work that needs to be done.

I hope you enjoy this volume of *Hazelnut News* and be sure to let me know if you have any questions or comments at: jason.fischbach@ces.uwex.edu.

Why Hazelnuts?

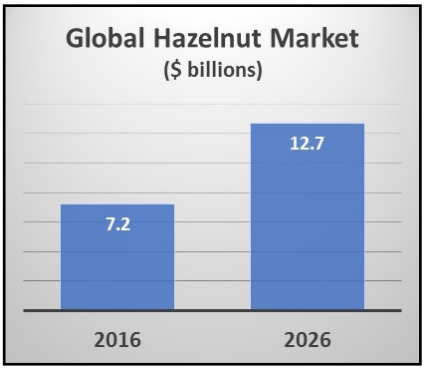
A Nut Crop for the Upper Midwest

The Upper Midwest does not have a large-scale nut crop and hazelnuts are the perfect candidate as they are native to the region and are well adapted to our soils and climate. Hazelnut is a unique crop because it can be used in so many different ways. The kernels, oil, and meal can be sold raw or used in a broad range of value-added food products like salad oils, spreadable nut butters, flour mixes, trail mixes, and confections. Besides food uses, the oil, shells, husks, and wood can be used as feedstock for bioenergy or, with additional research, biochemical applications.

A Heart Healthy Oil

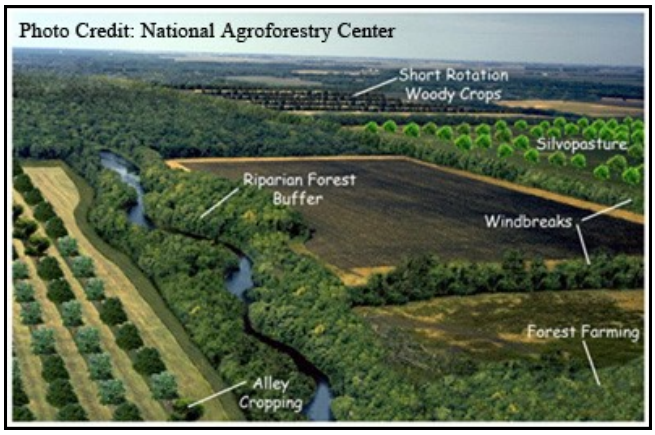
Monounsaturated oils are a heart healthy oil and considered an essential component of a healthy diet. American hazelnut is 81% oleic acid, making it one of the healthiest oils available, even more so than olive oil. Researchers are just beginning to explore the diversity of American hazelnut populations and it's likely there are amazing flavors to be discovered. With modern diets increasingly shifting from carbohydrates to healthy fats and proteins, hazelnut is well positioned to capture market share in the vegetable oil sector.

Growing Consumer Demand



More than 85% of global hazelnut production occurs in Turkey. Persistence Market Research projects the worldwide hazelnut market will grow from $7.2 billion in 2016 to $12.7 billion in 2026 and there is real question about where the hazelnuts will come from. By creating a hazelnut industry in the Upper Midwest our small and large-scale food processing companies in the region will have access to a local and sustainably-produced supply of hazelnuts, ensuring our region shares in the market growth.

A New Conservation Tool



Expensive land set-aside and government conservation programs such as CRP and CREP are designed to protect the environment *from* agriculture. A better option would be to protect the environment *with* agriculture. In other words, crops that generate income for growers *and* protect soil and water quality can protect our environment without costly government expenditures. Hazelnuts are envisioned as a foundational species for such systems and is a central crop in the University of Minnesota Forever Green program. This cutting-edge approach to crop development is working to bring perennial crops to the agricultural landscape. Because hazelnuts can be harvested mechanically they can be grown in large-scale plantings, and thus deployed in windbreaks, riparian buffers, or in alley-cropping systems. Hazelnut can truly change the way we farm...and achieve environmental protection.

Meet the UMHDI Research Team

When the UMHDI was launched in 2007, it was nothing more than a strategic plan. We had no funding and no staff. So, our first goal was to start to build a team of researchers and partner organizations to do the work outlined in the strategic plan. Recognizing that building a new woody crop industry takes many years, one of our goals has been to "institutionalize" the UMHDI to ensure that the project continues beyond the careers of any single individuals. That requires building a broad collaboration with many partners. Over the years our Research Team has grown and along with it our capacity to serve the emerging industry. That said, despite our many team members, only Lois Braun and Jason Fischbach currently have positions with duties specific to hazelnuts. The rest of our team members do what they can as time and funding allow. The UMHDI Research Team works closely with growers and partner organizations throughout the Upper Midwest and we are always looking for new partners and team members!

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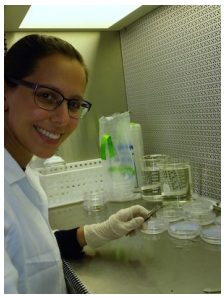

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chemistry of bitterness in hazelnuts

1. Breeding and Propagation

Hazelnut Improvement Program (HIP)

By far the number one priority for the UMHDI has been to develop improved germplasm for growers in the Upper Midwest and to do so in a way that maintains genetic diversity. The growers have told us loud and clear they want plants that do better than the currently available seedlings, but they also don't want a monocrop of one clonal cultivar.

In response, we launched the Hazelnut Improvement Program (HIP) to deliver locally-adapted genotypes to growers that are winter-hardy, resistant to Eastern Filbert Blight, and productive enough and with high enough kernel quality to support a commercially-viable industry. To that end, we've been pursuing a four-part strategy:

1. Hybrid Seedlings

In 2008 we conducted a survey of growers and found more than 130 growers in WI, MN, and IA with more than 65,000 hazelnut seedlings originating primarily from Badgersett Research Corporation, Forest Agriculture Enterprise, and the Arbor Day Foundation (Figure 1). The fact that all 65,000 plants were genetically unique and highly variable was, and continues to be, a challenge for growers, but an absolute treasure for plant breeders. We immediately began working with growers to identify the best of their seedlings for evaluation in replicated performance trials. Once we identified a high-performing plant we mound-layered the plant to create identical clones (Photo 1) and transplanted them to each of five Germplasm Trials (Photo 2). As of 2017 we have more than 150 selections being evaluated in the five trials and continue to add more as growers identify their best plants. Now with up to 9 years (5+ bearing years) of performance data for the oldest plants in our trials, we have selected the top 8 genotypes and are working to propagate them for growers to trial. As is discussed later in this newsletter, propagation remains a major bottleneck, but now that we've selected the top genotypes we and the growers have a decision to make: If we can successfully propagate these genotypes are growers willing to grow them on a large scale? On the one hand, we have conducted an economic analysis and the genotypes appear capable of supporting commercial production, assuming the industry can sell

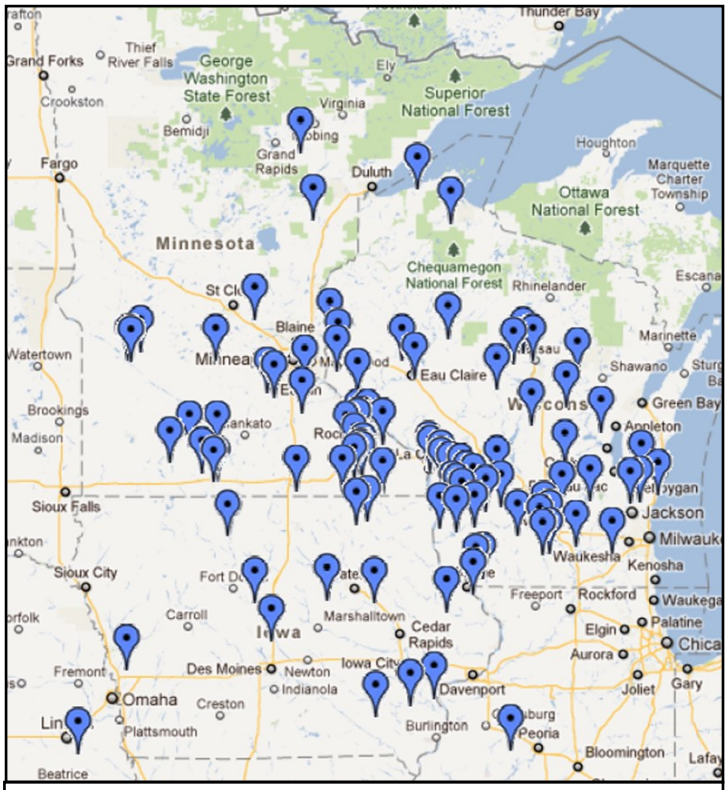


Figure 1. Known hazelnut growers in MN, WI, and IA. A major focus of our work the last decade has been finding the best plants from these plantings and evaluating them in replicated performance trials to find the best-of-the-best.

Photo 1. Many of the hybrid plants we've been evaluating in our trials were identified by growers themselves such as this plant at the Handeen/Arner Farm near Montevideo, MN. Ken Meter (left), Lois Braun (center), Heidi Claussen (right)

Hazelnut Improvement Program (HIP) (cont.)

kernels that are generally smaller than what is produced in Europe or Oregon. On the other hand, the performance data we have so far is from only three locations and only up to 5 bearing years. In our meeting this fall, this issue will be front and center...how aggressively to scale-up production of the top hybrid plants we've found so far.

Photo 2. Lois Braun collecting data in the St. Paul Germplasm Trial. The other trials are located in Bayfield, WI, Tomahawk, WI, Lake City, MN, and Lamberton, MN. The top performing plants from these trials are being propagated for growers to try.

2. American Hazelnut

The Upper Midwest lies right in the middle of the native range of American hazelnut (*Corylus americana*). On open sandy sites, particularly in Northern Wisconsin and Northern Minnesota, it is often the dominant shrub and in some years the plants are loaded with nuts. Plant breeders have historically viewed American hazelnut as primarily a source of winter-hardiness and disease resistance, but not as a potential crop itself due to the small nut-size. We take a slightly different view. We think American hazelnut has potential on its own, particularly for processing markets where kernel quality is more important than kernel size. Much like Peru is the epicenter of potato genetic diversity, MN/WI are the epicenter of hazelnut genetic diversity and our American hazelnut populations have never really been explored. Even if American hazelnut isn't suitable as a crop on its own, harnessing the genetic traits within the wild populations could greatly enhance breeding efforts toward developing locally-adapted hazelnut cultivars.

Photo 3. American hazelnut accessions at the Hayward State Tree Nursery in Hayward, WI. Since 2014 we have been planting half-sibling seedlings from wild American hazelnuts. At 2,500 plants and counting we are hoping to find high-performing plants and/or desirable traits.

In 2009 we began screening the wild hazelnut populations and what we've found is exciting. First, there is enormous genetic diversity within the population and, second, most of the diversity is within populations as opposed to across populations, meaning a good approach to finding top-performing plants is to screen individual populations (Demchik et al, 2017). In 2009 we began doing just that. Once we find a site of dense hazelnut, typically on Forest Service or County Forest lands, we then walk through the site and visually rate the cluster density of the top 100 plants. We then harvest the top 10 of those plants and based on the yield and kernel quality, we then choose the top 1-2 of those plants (Fischbach et al, 2010). A small portion of the crown is dug from the ground and transplanted to the Germplasm Trial in Bayfield. We've now screened more than 35 sites and have 60 accessions archived in Bayfield. We are currently working to propagate the plants further for replicated evaluation. The slow pace of propagation is frustrating, but we're excited about the population we've assembled and look forward to evaluating the accessions across multiple environments.

Hazelnut Improvement Program (HIP) (cont.)

In addition to the select accessions, we have also been collecting seed from the wild populations and growing out half-sibling families since 2014. We currently have more than 2500 plants growing at the Hayward State Tree Nursery in Hayward, WI (Photo 3). The hope is some of these plants are high-performing or have traits that can be used in a breeding program.

Backcross Seedlings

A traditional plant breeding program starts by assembling a population of genetically diverse plants, evaluating those plants for beneficial traits and then cross-pollinating the plants with beneficial traits to create a population of offspring. Those offspring are grown and the very best of those offspring are vegetatively propagated to evaluate in replicate across multiple locations. With the hybrid seedlings from the on-farm plantings we were able to start at the offspring stage, which is why we are further along with that program. But, we are also starting a new cycle by cross-pollinating the best of the on-farm hybrids with pollen from European plants from the Oregon State breeding program with the goal to combine the best traits from both sources. The offspring from these crosses, called backcross seedlings, are being grown out by Lois Braun at Minnesota (Photo 4) and the top plants from those seedlings will be vegetatively propagated for replicated evaluation likely starting in 2020. From then it'll be another 8 years or so before the best-of-the-best would be available to growers. The long-term viability of a hazelnut industry in the Upper Midwest will depend on a breeding pipeline that is continually working to improve the germplasm. This backcross program is a long-term project and will require patience and commitment by the University and funders to see to fruition, but will be well worth the wait.

Joint Performance Trials

Our Hazelnut Improvement Program is not the only effort to develop improved hazelnut germplasm in North America. Public breeders at Rutgers University, Oregon State University, University of Nebraska, and private and amateur breeders across the US and Canada also have programs underway. In collaboration with these breeders we are in the process of establishing Joint Performance Trials at 13 locations and counting. In the Upper Midwest we established the Trials at Bayfield, WI, Verona, WI, Spooner, WI, Centerville, IA, Fenton, IA, St. Paul, MN, and Staples, MN. These trials will allow us to evaluate the performance of the best germplasm from each program and the hope is some of the genotypes will be good enough for growers to use to scale-up the industry. We envision these trials as a service to the private, public, and hobby breeders that want a third party to evaluate their selections. Such evaluation is done routinely for most agricultural crops and helps ensure that growers are using germplasm most suited to their location.

Photo 4. New backcross seedlings in Rosemount, MN. With more than 5,000 seedlings planted since 2013, the intention is to find a few plants worth propagating and evaluating in replicate at multiple locations as we've been doing with the hybrid seedlings.

Photo 5. In-shell nuts and kernels from top selections from the on-farm hybrid seedling plantings. Work is underway to propagate these selections for growers to trial.

Vegetative Propagation—Low Tech

Propagating hazelnuts from seed is relatively easy. With a stratification period or breaking of dormancy with gibberellic acid, hazelnuts will readily germinate and grow in the field or in pots. The only tricky part is transplanting leaf-on hazelnuts as is discussed later in this newsletter.

Vegetative propagation is not so easy, particularly for hybrid and American hazelnut genotypes. To develop the limited number of propagules we've needed for populating the replicated germplasm trials we've relied on mound-layering and hardwood stem cuttings. Lois Braun has done much of the work and has published two protocols for growers interested in doing their own vegetative propagation. Mound-layering is perhaps the simplest option as it requires little more than rooting hormone, sawdust, and twist ties. The plant being propagated is coppiced in the winter or early-spring to force the plant to produce many vigorous shoots from the crown in the spring. In June, the basal portion of the stems are painted with rooting hormone and a twist tie is applied to each stem to girdle it. The bottom halves of the stems are then buried in a mound of sawdust. The stems grow the rest of the year and if all has worked each of the stems will have produced their own roots and the stems can be removed at the girdle point and transplanted to the field or into pots in the late fall. A full description of the mound-layering protocol can be found at our UMHDI website.

Stem cuttings are typically a great way to propagate plants, but we aren't so lucky with hazelnuts. We've been unable to generate a protocol that works for softwood stem cuttings and though we can get hardwood stem cuttings to work the success rate is relatively low. With some effort, growers can use hardwood stem cuttings to propagate their plants. Like with mound-layering, the plant to be propagated is coppiced in the winter or early-spring to force the plant to produce many new vigorous stems from the crown. The stems grow all year and are harvested as dormant sticks in the fall. The sticks are rooted in growth chambers with tightly controlled temperature and humidity. Up to 40% of these stems will produce roots, resulting in new plants that can be potted and grown for a season before being transplanted in the fall. New innovations being developed show potential for even better success with stem cuttings. Lois has published a detailed stem cutting protocol on our UMHDI website.

Photo 6. A rooted layer produced in 1 season through mound-layering. Mound-layering is effective, but a single plant will only yield a limited number of layers every couple of years so it takes awhile to build up numbers through mound-layering.

Photo 7. Hardwood stem cuttings. Producing hardwood stem cuttings requires careful control of temperature and humidity. The success rate is low, but the method can be useful for producing limited numbers of propagules.

We envision someday there being thousands of acres of hazelnuts in the Upper Midwest and producing that many copies of the elite cultivars will require high through-put propagation such as micropropagation (tissue culture). European hazelnuts are relatively easy to micropropagate, but the hybrids and American hazelnuts are proving to be very difficult, and is the primary bottleneck faced by the UMHDI right now.

Vegetative Propagation—High Tech

In concept, micropropagation is relatively straightforward. Nodes (a small piece of stem with an axillary bud) or shoot tips from highly juvenile stems are harvested from the source plant and placed in an agar-based medium. With the right combination of nutrients and plant growth hormones the nodes produce roots and then new shoots (Figure 2). At this point, the plant has been stabilized and has been successfully "isolated". These "isolates" can be grown in perpetuity and used as a source for producing new shoots. Once the plant is isolated, new shoots from the isolates are harvested, stuck in agar long enough to root and resume growth. Once rooted and growing, the shoot is then harvested and transplanted to a soilless potting mix. These "micro-cuttings" are grown for some time and then transplanted into pots and grown until ready for transplanting to the field as "liners" (Photo 8). Scale-up in this system can happen exponentially and quickly as 10-20 micro-cuttings can be produced per jar.

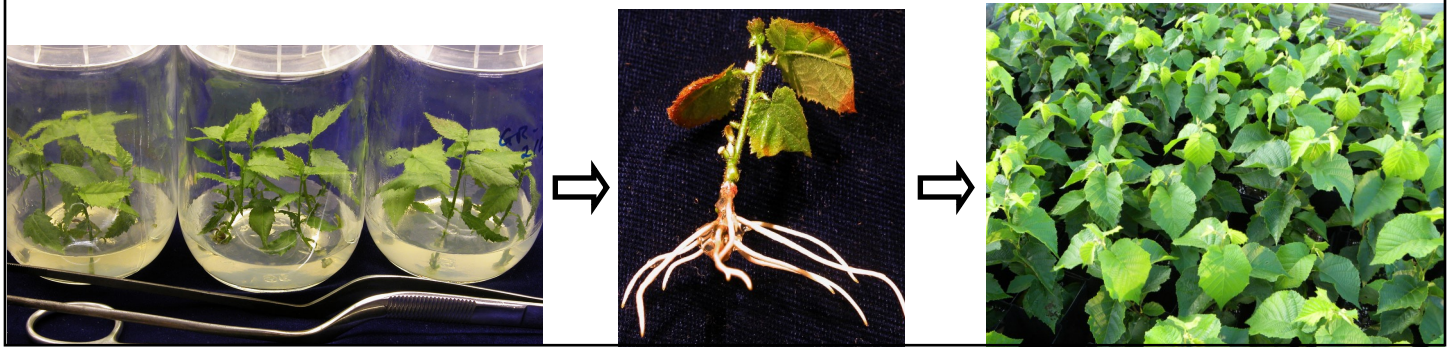
Ah, if only it was so easy with hazelnuts. Since 2009, Dr. Brent McCown and Knight Hollow Nursery have been working to develop a micropropagation protocol for our American and hybrid hazelnuts. Some genotypes have been relatively easy to work with. Others are highly "recalcitrant" and have required extensive trial and experimentation to coax into isolation and to generate the micro-cuttings in the agar. Dr. Jerry Cohen and his graduate students joined the effort in 2011 with the goal of developing a fundamental understanding of the physiology involved in rooting, shoot formation, and acclimation of hazelnuts. By better understanding the molecular pathways and how they vary among genotypes the hope is to develop protocols that work for all genotypes.

Photo 8. Ideally, field-ready liners will be planted when dormant (right) as leaf-on plants (left) can be challenging to establish. Work continues to ensure micropropagated plants can survive their first dormancy period.

One of the main challenges for both micropropagation and stem cuttings has been survival of the rooted cuttings through their first dormancy. To survive dormancy the plants must produce buds that will last through the dormancy period (winter) and continue growth the next spring. We still don't understand why, but many genotypes will go dormant before setting buds capable of resuming growth. Why these buds don't resume normal growth is unknown, but we suspect it is a combination of micro-nutrient deficiencies and length of the pre-dormancy growth phase.

We're hopeful we can soon develop reliable and feasible micropropagation protocols, because until we do any scale-up of top selections will rely on the slow methods of stem cuttings and mound-layering.

Figure 2. Micropropagation of hazelnuts. Once rooted and in active growth, micro-cuttings can be removed from the agar (left) and transplanted into potting mix for continued growth (middle). The method can be used to produce thousands of clonal propagules (right), but so far has only worked for a few of our selections.



2. Industry Infrastructure and Marketing

Grower Networks

The 2007 strategic plan calls for assisting growers in establishing the information sharing networks to help them learn from researchers and from each other as well as to communicate their needs to funders and policy-makers. Such grower networks and associations are key to any industry, but especially a new industry.

To facilitate information sharing and development of grower networks, we have been implementing a robust outreach education program. The 1st Annual Upper Midwest Hazelnut Growers Conference was held in 2010 and has been held every year since rotating across WI, MN, and IA. We've held an annual field day in Wisconsin since 2009 rotating throughout the state. We created and maintain an information portal for hazelnut growers at www.midwesthazelnuts.org. The website includes our many publications and information useful to beginning and established growers.

There is currently no single hazelnut grower association in the Upper Midwest, instead there are a number of non-profit organizations including Rural Advantage, Minnesota Hazelnut Foundation, Savanna Institute, Iowa Nut Growers Association, and Main Street Project each working in their own way to advance the hazelnut industry. There has not yet been a concerted effort to develop a unifying organization and at some point the growers may want to consider it, but with limited numbers of growers there may not yet be enough social capital (time and energy) to start and sustain another organization. Besides, these organizations are already doing great work!

We are currently working to develop clusters of growers organized around replicated germplasm trials we hope to establish in 2018. These clusters would help us learn about the performance of the advanced selections in the trials as well as implement and evaluate agronomic practices. The clusters would also serve as a nucleus and catalyst for building the supply chains as scale-up of the industry proceeds.

Photo 9. Eager learners at the 2016 Upper Midwest Hazelnut Growers Conference in Gays Mills, WI. Held annually since 2010, the conference is the best way for growers to learn from our research team and network with other growers.

Photo 10. The first annual Wisconsin Hazelnut Field Day in 2009 Maiden Rock, WI. Our annual field day is an opportunity for aspiring and established growers to learn from other growers.

Market/Supply Chain Development

In cooperation with the growers we have been working to build the supply chains needed to move product from the field to the consumer. One big issue that any new industry faces is to what extent the industry is driven by competition vs cooperation. Do individual growers act alone and compete for market share or do growers work together to pool production volumes and share expenses? Do growers pursue some form of vertical integration to own the nut production, processing, and marketing parts of the supply chain? Or, are the supply chain parts done independently from each other and under different ownerships? These issues matter as they can greatly affect who makes money in the industry now and into the future.

Photo 11. Hazelnut products from nuts grown in the Upper Midwest. Developing a new industry around a new crop requires an iterative approach of "push" and "pull". As we develop improved germplasm and increase supply we must also develop processing capacity and market demand.

To provide growers with examples of how other nut industries have organized themselves and structured their businesses Michelle Miller and Brady Williams from the UW-Madison Center for Integrated Agricultural Systems developed a series of case-studies on nut processing and marketing companies in the Midwest. These case-studies included the Chestnut Growers, Inc., Hammons Products Company, Heartland Nuts 'N More LLC, Missouri Northern Pecan Growers, and the Prairie Grove Chestnut Growers LLC. The hope is these case studies make hazelnut growers aware of the successes and mistakes of other nut industries.

Early on some growers decided to explore options for working together to pool production volumes and share in the expenses of the processing and marketing. The driving force for this cooperation was the requirement to have a food processing plant license for wholesaling hazelnut kernels and products made with the kernels. Minnesota and Iowa have cottage food laws that provide some limited exemptions to this requirement when selling direct to customers. Wisconsin does not have such an exemption and, regardless, scaled-up hazelnut production and sale of kernels, oil, meal, or value-added products will almost certainly require selling to retailers, restaurants, and food processors, for which a food processing plant license will be required. Obtaining such a license requires a facility and equipment that meets food code, which means significant expense. By sharing these expenses and pooling production volumes the growers hope to reduce costs of production and enter the market place with cost-competitive products.

With assistance from Jason Fischbach and countless hours of planning and meetings by the steering committee, the American Hazelnut Company (AHC) was formally incorporated in November of 2014 as a partnership-based Limited Liability Company. Currently with 17 grower-owners, the AHC is located in the Kickapoo Culinary Center in Gays Mills, WI and is currently producing and selling cold-pressed hazelnut oil, hazelnut flour, and raw hazelnut kernels. The AHC is actively seeking new members and is looking for more nuts to purchase.

The global hazelnut market is projected to grow from $7.2 billion today to $12.7 billion by 2026. One of the questions hazelnut growers and stakeholders in the Upper Midwest must soon answer is how aggressively to grow the industry, particularly as work is proceeding to develop competing new production areas worldwide. Any major expansion in the Upper Midwest will require significant financing for new plantings and processing capacity. Where will such financing and patient capital come from?

Product Development

Another aspect of our work has been to help the Upper Midwest better characterize the attributes of hazelnuts toward using the information for product differentiation efforts. Growers in our region insist that nuts from American hazelnut plants taste better than nuts from European hazelnut cultivars. To test that assertion Mike Demchik worked with the food sensory lab at North Carolina State University. Trained taste testers conducted a sensory analysis of selections of American hazelnut compared to an industry standard European cultivar, Tonda di Giffoni (Demchik et al., 2016). The results showed that some American hazelnut selections tasted better and had a more robust aroma than Tonda di Giffoni. The results support our vision that American hazelnut and/or the hybrids with European hazelnut can produce high-quality kernels different and perhaps better than kernels currently available in the marketplace.

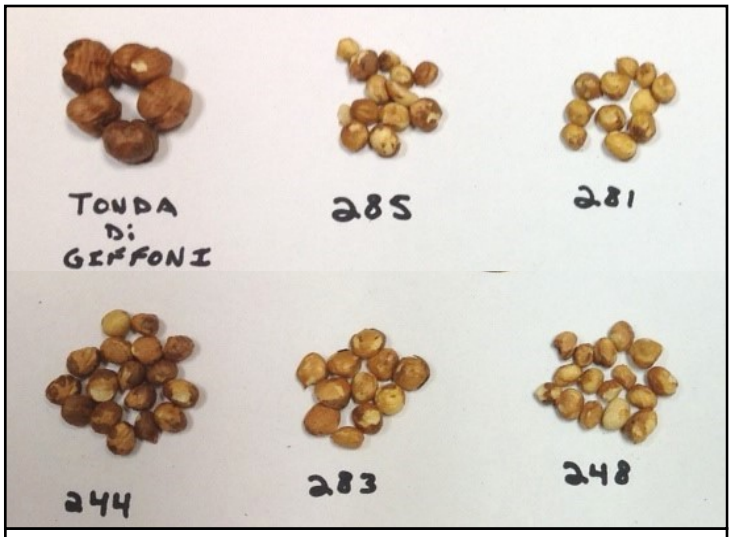


Photo 12. Kernels from American hazelnut may be small, but many selections have flavor and aroma that exceed that of industry standard European hazelnuts such as Tonda Di Giffoni (top left).

Given the diversity in flavor among the American hazelnut selections we tested, we have initiated a project to better understand the molecular aspects of hazelnut flavor. Dr. Devin Peterson and his graduate student Xue Wang at the Ohio State University have recently begun a project to isolate the compounds that confer both desirable and off-putting flavors. We'll be able to use this information in our breeding program to help us ensure we only select genotypes with superior flavor. Breeding for flavor is a growing priority across agriculture as consumers demand natural foods with fewer flavor additives and enhancers. With the genetic treasure of American hazelnut right in our backyard we are excited to be on the front edge of this flavor work.

We have also been working to develop post-harvest processing protocols in order to optimize flavor and quality. To date, we have found that lipoxygenase activity varies across genotypes, thus selecting for genotypes with low activity may extend shelf-life of ground or oil products.

Photo 13. Large-scale hazelnut production will yield large volumes of shell and husk material. Developing markets for the material will be key to maximizing profitability of hazelnut production and processing.

Another aspect of our market development work is finding uses for hazelnut processing byproducts such as the shell and husk (Photo 13). Shell and husk material can be used as mulch or even as a fuel source, but perhaps there are other higher value uses. Mike Demchik has been focusing on the phenolic content of the byproducts. Phenolics are the bioactive compounds in plants that are typically involved in the plant's natural defenses against pests and environmental stressors. Phenolics tend to have anti-oxidant properties that are sought after in the health food industry. So far, Mike has found high phenolic content in the husks in particular and is now working to characterize the specific compounds. Mike is also working to determine whether hazelnuts have anti-microbial properties that could be of use medicinally.

3. Agronomic and Production Systems

We envision hazelnuts being grown in the Upper Midwest in hedgerows that are mechanically harvested by removing the clusters from the shrub (Photo 14). Such a system is different than currently used in Oregon, where nuts fall from trees and are swept or vacuumed off the bare orchard floor (Photo 15). Our publication "A Production and Economic Model for Hedgerow Hazelnut Production in the Midwestern United States" details such a system and identifies additional work that needs to be done to optimize the system. We envision such a production system for three main reasons: 1) The current germplasm being grown by producers and the germplasm we are developing has the shrub growth habit of American hazelnut, 2) Harvesting nuts directly from the shrub reduces some food safety hazards compared to sweeping the nuts off the ground, and 3) Harvesting the nuts directly from the shrub allows for vegetation on the orchard floor, improving biodiversity and the conservation value of the plantings. Because the hedgerow production system is new, there are many agronomic questions that we've been working to answer.

Photo 14. Mechanical harvest of hybrid hazelnuts grown in hedgerows. The shrub-type growth habit of hybrid and American hazelnut makes it amendable to over-the-top mechanical harvest and provides opportunities to use hazelnuts as a dual-purpose nut crop and shrub component in soil and water conservation plantings, such as riparian buffers. (Photo credit: Dave Bohnhoff)

Establishing New Plantings

In our early survey work we discovered that growers were experiencing significant mortality in the 1st and 2nd years after planting. This mortality was due mainly to the combination of fragile tubelings and inexperienced growers losing the battle to wind, weeds, and herbivory. In 2011, Jason Fischbach began a series of grow tube trials to better understand how grow tubes affect plant mortality and growth (Photo 16). So far, we've learned that any form of tree tube will help establishment success as the tubes protect the plants from rabbit herbivory and wind and make it easier to use mowing and herbicides to control weeds. We've also learned that shorter tubes (18") are likely better than taller tubes as the tall tubes result in top-heavy stems prone to breaking once the plants start producing nuts.

Photo 15. European hazelnut cultivars grown in Oregon (as shown here) are grown as small trees. The orchard floor is maintained vegetation free and the nuts fall from the trees and are windrowed and swept off the orchard floor.

Lois Braun has also been conducting weed control trials to evaluate plant survival and growth in response to herbicides, landscape fabric, wood chip mulch, and mowing (Photo 17). Not surprisingly, the results indicate any form of weed control results in larger

Establishing New Plantings, (cont.)

plants compared to no weed control. The beneficial effects of weed control have long been understood for establishment of perennial crops, but for some reason there persists a belief in the hazelnut community that hazelnuts can handle weed competition and that early stress will somehow force the plant to develop a healthier root system.

Photo 16. Grow tubes protect plants from wind and herbivory and can make it easier to mow or use broad spectrum herbicides like glyphosate or acetic acid. 30" (left) and 18" (middle) tubes will work, but the taller tubes can result in top heavy stems that can break once loaded with nuts.

Photo 17. Reducing weed competition during the establishment phase results in more vigorous and larger plants. Ongoing weed management trials will help inform economic enterprise budgets to determine the most cost-effective methods to control weeds in hazelnut plantings.

Plant Management

Once plants are established, there are important questions as to fertilization and pruning. Hazelnuts require nitrogen to produce consistent nut crops, but how much additional nitrogen must be added and when are unknown. Likewise, little is known as to phosphorus, potassium, and micronutrient needs, particularly because the existing and experimental germplasm has American hazelnut in the parentage. American hazelnut grows primarily on nutrient poor sandy soils in the wild and may be highly efficient at scavenging and recycling nutrients, but we just don't yet know. We also don't yet know best ways to prune the hazelnuts. Some suggest renewal pruning as is done with blueberries is best in order to remove the oldest wood every year. Others suggest periodic coppicing to rejuvenate the plant.

To answer the fertilization and pruning questions, we have been conducting a series of experiments since 2012. Agronomic experiments with woody crops are best done with clonal plant material in order to avoid difference in genetics from confounding the experimental treatments. Because hazelnuts are difficult to vegetatively propagate it has taken us some time to get fertilization and pruning trials established. Likewise given the phenotypic and genetic diversity we are working with it is likely agronomic recommendations will vary based on the genotype. For example, genotypes that tend to spread through suckering may require different management than genotypes that stay relatively compact.

Lois Braun has established a series of nitrogen fertilization trials in Minnesota (Photo 18). The goal is to develop a leaf-tissue testing protocol that can be used to make nitrogen fertilization recommendations. Such systems are routinely used for woody crops and having such a system for hazelnuts in the Upper Midwest would help growers ensure plants have sufficient nitrogen for consistent yields and avoid over application and possible nitrate losses to the environment. Lois expects to have a protocol finalized by 2020.

Lois has also been conducting a series of pruning trials. It is still too early to provide definitive results, but some trends are emerging. For example, some genotypes regrow aggressively after being coppiced while others regrow very slowly if at all. Pruning a hazelnut plant by hedging is not likely a viable option (Photo 19) as it simply promotes more aggressive top growth. The plants do seem to respond to renewal pruning (Photo 19) and such pruning is likely going to

Plant Management, (cont.)

be the best method to retain vigor and productivity while maintaining a manageable plant size. However, we need to track productivity over a series of pruning cycles before making specific pruning recommendations. Moreover, removing old stems by hand, as is done with blueberries, would be a major labor challenge if hazelnuts are grown at significant scale, so we'll need to develop mechanical methods to conduct the renewal pruning.

We are also addressing the question of plant spacing, with two trials in Minnesota that compare plants spaced at 3, 6, 9 and 12 feet. One of the key economic variables of the hedgerow system is filling the available growing space as quickly as possible with fruiting wood. Tighter initial spacings would help, but we don't yet know if it is worth the added cost or what will happen with interplant competition.

If we can find the funding our intention is to conduct a series of agronomic trials with the select genotypes being planted in the Joint Performance Trials. This will allow us to apply what we've learned in our preliminary trials to the top selections and develop management recommendations specific to each select genotype.

Photo 18. Nitrogen fertilization trials are being conducted by Lois Braun at multiple locations in Minnesota. The intention is to develop leaf testing protocols that can be used to make nitrogen fertilization recommendations.

Photo 19. On their own, most hybrid hazelnuts will grow into large unmanageable trees. Removing old non-productive wood can manage plant size while promoting growth of more vigorous and fruitful stems. We are working to develop the most effective and efficient method to rejuvenate the stems. Hedging the plants with heading cuts (right) is not a good idea as new growth originates from the top of the plant. Renewal pruning to remove the oldest stems every few years is yielding good results, but more work is needed to determine the cost-effectiveness and long-term effect on productivity.

4. Harvesting and Processing Equipment

Harvesting

The majority of hazelnuts grown in the Upper Midwest are currently harvested by hand. The clusters are stripped from the shrub and put into produce bins or mesh onion bags. Harvest rates can vary widely depending on the harvester, shrub size, and cluster density. Hand-harvest trials have measured harvest rates at roughly 13 lbs in-shell nuts per hour. At $10/hr that works out to a labor cost of $0.77/lb. Even if harvest labor was available, it simply isn't cost effective to hand harvest hazelnuts at a large scale. Also, once the nuts are ripe it is important to harvest immediately to reduce loss to rodents and blue jays and hand-harvesting may take too long. Our vision is for harvesting equipment that removes the clusters directly from the shrub (as opposed to picking the nuts off the ground after they fall from the shrub) and also does the de-husking in the field. At this point such equipment doesn't exist and will have to be engineered and built.

Photo 20. BEI harvester showing the sway bars used to detach the fruit or nuts from the plant as they pass through the harvester tunnel. The unit shown here is designed for high-bush blueberries before they reach mature size. It is being used here for black currants.

The best way to build new equipment is to find existing equipment that works okay and make it better. Growers themselves are taking the lead in these efforts. Harvest equipment built for shrub-fruits like blueberries and aronia both have potential for our shrub-type hazelnuts. The BEI harvester (Photos 20, 21) that uses sway-action bars is currently being used by some growers in Minnesota and Wisconsin, and is reported to work adequately well with harvest rates around 400 lbs in-shell per hour. The effectiveness of the harvester is limited mainly by shrub size and uneven ripening within a planting. Plantings with single cultivar rows will help with the uneven ripening issue. Managing plant size and architecture through a combination of breeding and pruning will also help optimize harvest.

Photo 21. This larger size BEI unit designed for mature high-bush blueberries is currently being used with success by hazelnut growers with mature hazelnut shrubs. (Photo Credit: Linda Meschke)

To date, our research team has only begun to investigate the harvesting technology and any work in the area will be contingent on finding funding. Once we secure the funding our intent is to conduct a series of trials to better understand the optimal force and mechanism for detaching the cluster from the shrub while minimizing damage to the plant. We'll also trial various harvesters from other crops and identify a least-cost strategy for optimizing the harvest equipment for hazelnuts. In addition, we'll work to integrate de-husking capability into the harvest equipment for removal of the husks during harvest. Such de-husking capacity would eliminate the expensive and time-consuming step of drying the nut clusters before removing the husks.

Post-Harvest Processing

One of goals in the 2007 strategic plan was to build processing infrastructure to ensure that growers producing nuts would have a means to process and sell them. To that end, one of our first tasks was to find and/or develop appropriately-scaled processing equipment. The process of de-husking hazelnuts is relatively easy, but with the small in-shell nut size compared to European hazelnuts and the low consumer demand for in-shell nuts, it will be necessary to crack the hazelnuts and separate the shell from the kernel.

In 2009, we convened a Hazelnut Processing Committee comprised of growers that had been working to assemble their own processing lines. The committee's task was to evaluate existing processing equipment and to design and build any equipment that wasn't yet available. At the time there was hazelnut processing equipment available commercially, but it was sized for a scale of production larger than ours. Plus, it was optimized for the relatively uniform, large, and thin-shelled European hazelnuts. The committee determined that a husker, a cracker, and sorting equipment would need to be designed and built. After much innovative work by many growers, the industry now has early-stage equipment. Most growers are now using a barrel husker or similar type machine to remove the dried husks from the nuts (Photo 22). The nuts are then separated into size-classes with a roller-sizer (Photo 23). Cracking options are still not perfect, but most growers are using the Drill-Cracker (Photo 24) followed by an aspirator (Photo 25) of some kind to separate the kernel from the shell fragments.

There are now at least five growers with some form of a processing line operating in the Upper Midwest. To help the growers evaluate the economics of their hazelnut processing lines we developed a processing enterprise budgeting tool that is available on the UMHDI website. This tool allows growers to evaluate each step of their processing line and it provides a common set of metrics for growers to use when comparing processing equipment.

In 2013, Dave Bohnhoff and recently Scott Sanford of the UW-Madison Department of Biological Systems Engineering joined our research team to provide assistance designing and testing hazelnut processing equipment. In particular, through their student design projects, Dave's students have developed a number of prototypes to test different low-cost approaches to sizing, cracking, and kernel-shell separation. As funding allows, the intention is to turn these proof-of-concept prototypes into fully-functioning equipment for processors to use.

Photo 22 Low-cost barrel husker to remove husks from in-shell nuts (left). The X2000 husker is based on the barrel husker, but can be continuously fed (right).

Photo 23. Student designed rotary-drum sizer (left) and the Badger roller-sizer (right) separate in-shell nuts into different size classes.

Photo 24 (left). Drill Cracker being fed with from a plastic hopper. **Photo 25 (right).** Badger aspirator to separate shell fragments from kernels after cracking.

UMHDI Field Trial Locations

Bayfield, WI
Outlaw Vineyard and Orchard
UMHDI Germplasm Trial (est. 2009)
Wisconsin Production Trial (est. 2011)
Joint Performance Trial (est. 2017)

Hayward, WI
Hayward State Tree Nursery
UMHDI American Hazelnut Seedling Orchard (est. 2014)
Grow Tube Trial (est. 2016)

Spooner, WI
Spooner Agricultural Research Station
Wisconsin Production Trial (est. 2011)
Joint Performance Trial (est. 2017)

Finley, WI
Cranberry Creek Cranberries
Grow Tube Trial (est. 2016)
American Hazelnut Half-Sib Trial (est. 2016)

Tomahawk, WI
UWSP Treehaven Field Station
UMHDI Germplasm Trial (est. 2010)
American Hazelnut Half-Sib Trial (est. 2016)

Stoughton, WI
Emancipation Acres
Wisconsin Production Trial (est. 2011)

UMHDI Field Trial Locations, (cont.)

Verona, WI
West Madison Agricultural Research Station

Ashland, WI
Northern Great Lakes Visitor Center
UMHDI Germplasm Trial (est. 2014)

Rosemount, MN
Rosemount Research and Outreach Center
Nitrogen Trials (est. 2011)
Pruning Trials (est. 2012)
Weed Control Trials (est. 2013)

Rosemount, MN
Vermillion Highlands
Backcross Seedling Orchard (est. 2015)

St. Paul, MN
UMN St. Paul Campus
UMHDI Germplasm Trial (est. 2009)
Backcross Seedling Orchard (est. 2013)

Staples, MN
Central Lakes Ag Center
Nitrogen Trial (est. 2012)

UMHDI Field Trial Locations, (cont.)

Becker, MN
Sand Plain Research Farm
Nitrogen Trial (est. 2012)

Lake City, MN
Hazelnut Valley Farm
UMHDI Germplasm Trial (est. 2009)

Montevideo, MN
Gibson Farms
Pruning Trials (est. 2013)

Lamberton, MN
Southwest Research and Outreach Center
UMHDI Germplasm Trial (est. 2009)

Wykoff, MN
Ramaker Farms
Nitrogen Trial (est. 2011)

Waseca, MN
Southern Outreach and Research Center
Nitrogen Trial (est. 2013)

Publications from the UMHDI Research Team

Journal Publications

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Publications from the UMHDI Research Team

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Sustainable Agriculture Research and Education (SARE) Grant
"Commercialization of Hazelnuts for Growers in the Upper Midwest"
October 1, 2015 through September 30, 2018

Specialty Crops Research Initiative (SCRI) Grant
"Developing Native and Native-European Hybrid Hazelnut Germplasm and Agronomics for the Upper Midwest"
Sept 1, 2011 through Aug 31, 2016

Sustainable Agriculture Research and Education (SARE) Grant
"Developing Hazelnut Germplasm for the Upper Midwest"
Oct 1, 2010 through Sept 30, 2013

WI DATCP Specialty Crop Block Grant
"Improving Bush-Type Hazelnuts for Commercial Production Through Cooperative Regional Breeding and Evaluation"
November 2009 through August 2012

WI DATCP Buy Local Buy Wisconsin Grant 2014
"Connecting Growers and Buyers of Hazelnuts in Wisconsin Through the American Hazelnut Company"
March 2014 through February 2016

WI DATCP Specialty Crop Block Grant 10-019
"Increasing Sales and Production of Wisconsin-Grown Hazelnuts Through Development of Mobile Post-Harvest Processing"
October 2010 through December 2011

University of Wisconsin System Applied Research Grant Program
"Scaling-Up Hazelnuts in the Upper Midwest"
July 2015-June 2017

University of Wisconsin Consortium for Extension and Research in Agriculture and Natural Resources
"On-Farm Hybrid Hazelnut Breeding: A Model for Development of Multi-Functional Crops for the Bioeconomy"
July 2008 - June 2009

Minnesota Department of Agriculture Crops Research Grant
"Developing a Hybrid Hazelnut Production Package for Minnesota"

For comments or questions relating to the content of this newsletter please contact Jason Fischbach at 715-373-6104 ext 5 or jason.fischbach@ces.uwex.edu. Suggestions for future newsletter topics are also welcomed.

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"Sustaining Hazelnut Breeding and Agronomic Research at the University of MN."
Oct 1 2015 to July 30, 2017.

Minnesota Department of Agriculture Specialty Crop Block Grant
"Developing Native and Native-European Hybrid Hazelnut Germplasm and Agronomics for Minnesota"
Nov 25 2009 through Nov 30, 2011

University of Minnesota--Institute on Renewable Energy and the Environment
"Developing Native Hazelnut and Native-European Hybrid Hazelnut Germplasm and Agronomics for the Upper Midwest"
Sept 1, 2011 through Aug 31, 2016

University of Minnesota--Rapid Agricultural Response Fund
"Hazelnuts as a Multifunctional New Crop for Minnesota"
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"EQUIP Eligible Farmer Participatory Research in Propagation of Hybrid Hazelnut for Productive Conservation on Working Land"
2008-2009

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