A Production and Economic Model for Hedgerow Hazelnut Production in the Midwestern United States

Jason Fischbach & Lois Braun

February 2017

Upper Midwest Hazelnut Development Initiative

UW Extension

Forever Green

Hazelnut Improvement Program

The **Upper Midwest Hazelnut Development Initiative** (UMHDI) is a collaboration of researchers at the University of Wisconsin and University of Minnesota working with early-adopter growers and stakeholders to develop a sustainable hazelnut industry in the Upper Midwest. The **Hazelnut Improvement Program** (HIP) is a participatory hazelnut breeding program involving growers and University researchers. More information about the UMHDI or HIP can be found at www.midwesthazelnuts.org or by calling 715-373-6104 ext 5.

This report could not have been possible without the great work of other members of the UMHDI Research Team, in particular: Dr. Mike Demchik (University of Wisconsin—Stevens Point), Dr. Brent McCown (Knight Hollow Nursery), and Dr. Don Wyse (University of Minnesota—St. Paul). Many thanks as well to the interns and research assistants at U of MN and UW-Extension for their careful data collection. Finally, the emerging hazelnut industry in the Upper Midwest is a product of the many early-adopter growers that have carried the weight of developing their new industry.

This report was supported by grants from the United States Department of Agriculture — National Institute of Food and Agriculture (USDA-NIFA) Specialty Crops Research Initiative (SCRI), Wisconsin Specialty Crop Block Grant program (SCBG), and the Sustainable Agriculture Research and Education (SARE) Farmer/ Rancher Grant program.

Corresponding Author: Jason Fischbach, UW-Extension Food and Energy Woody Crop Specialist

jason.fischbach@ces.uwex.edu 715-373-6104 ext 5.

Publication design and layout by: Jason Fischbach

Cover photo credits: Photo of Lois Braun in Block C of the St. Paul Hazelnut Germplasm Performance Trial—Dave Hansen

Editorial reviews provided by Mike Demchik and Brent McCown

Introduction

Efforts to develop suitable hazelnut genetics for the Eastern and Midwestern United States extend back more than 100 years and have focused on combining the nut size and productivity of European hazelnut (*Corylus avellana*) with the winter hardiness and Eastern Filbert Blight (EFB) resistance of American hazelnut (*Corylus americana*) (Molnar et al, 2005). These efforts have been widespread over the years with breeding work conducted in Pennsylvania, New York, Wisconsin, Minnesota, and Maryland by individuals with an interest and passion for hazelnut breeding, but often lacking the resources and institutional longevity necessary to bring proven cultivars to market. In the Upper Midwest, first Carl Weschke of River Falls, WI (Weschke, 1954) and now Phil Rutter of Canton, MN (Rutter, 1991) and Mark Shepard of Viola, WI (Shepard, 2013) have been establishing half-sibling populations of *C. avellana* x *americana* hybrid seedlings and saving seed from top performing plants. Seedlings from these top plants have been sold to early-adopter growers throughout the Midwest with at least 135 such growers in WI and MN alone growing a total of nearly 70,000 seedlings (Fischbach, 2010).

Upper Midwest Hazelnut Development Initiative

In order to help develop a hazelnut industry in the Upper Midwest, we launched the Upper Midwest Hazelnut Development Initiative (UMHDI) in 2007 with four primary objectives: 1) Develop proven hazelnut germplasm capable of supporting an economically-viable hazelnut industry in the Upper Midwest, 2) Develop propagation protocols necessary to provide clonal material of select genotypes to growers at reasonable cost, 3) Develop appropriately-scaled harvesting and processing equipment tailored to the select germplasm, and 4) Develop an agronomic and production system with a robust outreach education program to support sustainable hazelnut production. In this paper we outline the hedgerow production system we envision for the Upper Midwest and present genotype performance and economic data to support the system.

Hedgerow Production System

Commercial hazelnut production in the U.S. is centered in the Willamette Valley of Oregon and is based on tree-form cultivars of *C. avellana* where large in-shell nuts fall free from the husk when ripe and are swept off the orchard floor. The system we envision for the Upper Midwest is modelled after bush-fruit systems with nut clusters mechanically harvested direct from hazelnut hedgerows (Photo 1). We envision a Midwest hazelnut industry based on high volume production of relatively small but high-quality uniform kernels for fresh and processing markets. Our focus has been to develop precocious, high-yielding, compact, multi-stem genotypes with the American hazelnut growth form (Photo 2). We are working to adapt blueberry and Aronia harvesting equipment

Photo 1. In-husk nut clusters are harvested directly from the hedgerows. Growers are currently using blueberry harvesters, but work is underway to develop more effective equipment. Photo: Dave Bohnhoff

to remove the clusters of in-husk nuts from the hedgerow and mechanically remove the husk as part of the harvest process. We are also developing mechanized pruning and hedgerow management systems.

The advantages of the hedgerow system we envision are threefold. First, a hedgerow system accommodates the natural bushy growth habit of native *C. americana* and its hybrids, allowing us to select first generation high-performing germplasm directly from existing on-farm and wild populations. Second, harvesting the nuts directly from the hedgerow allows for a more biologically diverse orchard floor that better protects water and soil quality. Finally, harvesting directly from the hedgerow avoids some of the food safety risks of sweeping nuts off the ground. The primary disadvantage of the hedgerow system is a possible reduction in per acre yields compared to the Oregon tree-based model due to the open row middles between hedgerows necessary for harvesting and equipment access. At maturity, an Oregon planting has a closed canopy with nearly 100% of the acre in production with estimated yields of over 2800 lbs of in-shell nuts per acre (Miller et al., 2013). Even by maximizing fruiting area through narrow hedgerows and narrow row middles the hedgerow system will utilize roughly only 50% of an acre. Whether per acre yields of the hedgerow system will actually be lower than the Oregon tree-based system depends on the productivity of the germplasm, and whether it matters economically depends ultimately on the per pound cost of production and market value of the nuts.

Performance and Production Potential of Select Hybrids

Working under the hypothesis that individual genotypes capable of supporting a commercially viable hedgerow production system already exist in the hybrid and wild *C. americana* populations in the Upper Midwest we launched the Hazelnut Improvement Program in 2007 to find and evaluate these genotypes. First, we screened (and continue to screen) on-farm plantings of hybrid seedlings populated with material primarily from the Badgersett Research Corporation, Forest Agriculture Enterprises, and the Arbor Day programs (Fischbach et al., 2011). Then, in 2009 we began establishing replicated performance trials at five Midwestern locations (St. Paul, Lake City, and Lamberton, MN in 2009, and Bayfield and Tomahawk, WI in 2010) and populating them with clones of the highest-performing plants identified in the on-farm plantings. The clonal propagules have been generated through a combination of mound-layering and stem cuttings. We now have up to six bearing years of performance data from these trials and have identified select genotypes based on those data (Braun et al., in review). The top genotypes were selected on the basis of precocity, kernel sphericity and size, annual yield, yield density (lbs of kernel per square foot of canopy coverage), and susceptibility to eastern filbert blight. We anticipate providing clonal material of these genotypes to growers for limited trial starting in 2017.

Photo 2. Our top eight selections such as this one (Cuddy 2-28 at age 6 in Bayfield) are precocious and compact with high yield densities. Photo: Jason Fischbach

Kernel Yield

Table 1 shows the average annual per plant kernel yields by plant age of the top 19 genotypes based on performance at the St. Paul and Bayfield locations. Genotypes in bold are the top 8 as identified by Braun et al., in review). On average, this cohort of genotypes starts producing nuts by age 4 in St. Paul and age 5 in Bayfield with year 1 being the mound-layering or stem-cutting propagation year. It is important to note, that because new genotypes are added to the trials as they are identified in the on-farm plantings, not all genotypes are the same age in a given year and, therefore, the plant ages are not the same as the calendar year for all genotypes. By age 7, the average kernel yields of the top 19 genotypes were 6.3 and 8.4 ounces/plant at Bayfield and St. Paul, respectively.

Bayfield					
Genotype	4	5	6	7	8
	--------oz kernel/plant--------				
SpC-2D5	**0.0**	**2.3**	**6.1**		
Arb 4-3	**0.2**	**1.9**	**4.2**		
Arb 7-21	0.0	0.6	3.3		
Arb 7-1	0.3	3.3	2.8		
Cuddy 2-28	**0.3**	**1.1**	**8.4**	**6.7**	
Rose 9-2	**0.0**	**2.0**	**3.4**	**13.7**	
Price W41	**0.0**	**1.0**	**4.3**	**7.9**	
Gibs 5-15	**0.0**	**0.1**	**2.4**	**4.9**	
Gibs 6-23	0.0	2.4	3.9	7.4	
Stap N7-6	0.0	2.1	5.9	5.3	
Stap N2-7	0.1	0.3	2.4	10.1	
Gunth PC	0.0	0.0	1.1	2.8	4.4
Stap S2-7	0.0	0.8	2.7	5.6	5.9
Rose 18-10	0.0	0.4	2.6	4.3	8.9
Heas D	0.1	0.5	1.4	3.4	5.7
Minar 342	**0.0**	**0.0**	**0.4**	**4.8**	**9.6**
Hand Fats	0.0	0.0	1.5	5.8	3.1
Eric 5-13	**0.0**	**0.2**	**1.2**	**5.5**	**11.5**
Heas B	0.0	0.1	1.4	5.7	0.9
Average	**0.1**	**1.0**	**3.1**	**6.3**	**6.3**

St. Paul						
Genotype	4	5	6	7	8	9
	------------oz kernel/plant-----------					
SpC-2D5	**1.8**	**4.0**	**15.2**			
Arb4-3	**2.2**		**11.3**			
Arb7-21	0.7	4.7	10.0			
Arb7-1	1.7	4.8	9.2			
Cuddy2-28	**0.1**	**2.2**	**7.8**	**11.3**		
Rose9-2			**6.6**	**15.7**		
PriceW41		**7.1**	**3.3**	**14.4**		
Gibs 5-15	**1.9**	**1.2**	**4.4**	**16.0**		
Gibs6-23	0.4	1.3	4.4	8.0		
StapN7-6		0.3	2.0	14.1	5.2	22.3
StapN2-7			1.0		16.6	
GunthPC	0.1	0.5	5.6	3.2	9.4	
StapS2-7	0.1	2.3	3.2	3.8	14.3	
Rose18-10		0.9	3.2	4.8	6.1	
HeasD		0.5	1.2	1.4	7.8	10.0
Minar342				**4.5**	**16.1**	
HandFats			1.6	10.1	4.1	15.0
Eric5-13		**0.4**	**1.5**	**3.9**	**9.9**	**14.6**
HeasB		1.7	1.1	6.4	11.9	17.5
Average	**1.0**	**2.3**	**5.2**	**8.4**	**10.1**	**15.9**

Table 1. Average per plant kernel yields by plant age of 19 top-performing hybrid hazelnuts at St. Paul and Bayfield. Genotypes in bold are the top 8 genotypes based on a combination of yield and kernel quality as selected by Braun et al. (in review). Genotypes are listed by age cohort with the most recent entries to the trials starting at the top.

The trial plantings were established at a density of 484 (6'x15') and 726 (5'x12') plants/acre at Bayfield and St. Paul, respectively. As is discussed below, the ideal plant density is not yet known, but at the 726 plants/acre density the extrapolated per acre yields of the average of the top 19 genotypes at age 7 would be 285 lbs/acre at Bayfield and 380 lbs/acre at St. Paul. The extrapolated average per acre kernel yields of the top 6 genotypes at age 7 is even higher with 330 and 500 lbs/acre at Bayfield and St. Paul, respectively. For perspective, the projected per acre yields at age 7 for the Oregon tree-based system with improved cultivars is 1100 lbs of in-shell nuts, which at 46% kernel would be roughly 500 lbs kernel/acre (Miller et al, 2013).

Early work to quantify yield potential of hybrid hazelnuts in the Upper Midwest found the average yields of the top plants varied significantly across locations (Fischbach and Braun, 2012). We anticipate the same will be true with the select genotypes and growers on high quality sites should expect bigger plants, larger nuts, and higher per plant yields compared to lower quality sites. Interestingly, as will be discussed later, site quality mainly results in bigger plants and not necessarily higher yield densities. Thus, lower quality sites may have an advantage over higher quality sites as the smaller plants may be easier to manage.

Figure 1. In-shell nuts (bottom), raw kernels (middle), and roasted kernels (top) from our top eight selections. Nuts shown are from the St. Paul planting.

Kernel Quality

Figure 1 shows the 2016 in-shell nuts and kernels for the top 8 genotypes at the St. Paul location. The in-shell nuts are considerably smaller compared to European hazelnut cultivars. Our breeding program as well as other programs in the Eastern US are working to develop genotypes that produce larger in-shell nuts than those shown in Figure 1, but sale of in-shell nuts to the end consumer is not likely the future of the Midwest industry. There is declining demand for in-shell nuts in North America and nearly all of the Oregon production of in-shell nuts is exported. As such, the focus of our program is total kernel production and kernel quality.

Kernel size of the top selections in Figure 1 is generally smaller than *C. avellana* varieties but the nuts are relatively spherical with little to no fiber. Sphericity is an index of roundness and is important for achieving an even roast during processing. Perfectly round nuts would have a value of 100. The sphericity of the top 8 genotypes ranged between 80 (SpC-2D5) to 92 (Gibs 5-15) with an average of 85 (Braun et al., in review). For European hazelnuts, ranges of 71 to 87 (Hosseinpout et al., 2013) and 69 to 97 (Ercisli et al., 2011) compare closely to our hybrids. Table 2 shows the average percent kernel and average individual kernel weights for the top 19 genotypes at St. Paul and Bayfield. There is considerable variability among genotypes and clearly the more fertile soils and longer growing season at St. Paul result in a higher percent kernel and larger kernel. There is variability among the genotypes as to pellicle removal in response to roasting. The pellicle falls free from some genotypes (Gibs 5-15) but remains attached for others (Cuddy 2-28). Steam blanching may be necessary for genotypes with harder to remove pellicles. The ability to remove the pellicle is significant as bitterness and other off-putting flavors are often in the pellicle. However, the pellicle also may contain health-promoting phenolics.

The average width of the hazelnut kernels from our top selections range from 8 to 12mm (data not shown), which means our Midwest-grown hazelnuts would fall into the Medium, Small, or Whole & Broken size classes used for Oregon hazelnuts. As shown in Table 2, growing conditions will affect kernel size with higher fertility sites producing larger kernels, but even on the best sites, kernel size will likely be smaller than kernels from Oregon. The small size kernels from these initial selections will likely require aggressive marketing and consumer education if selling whole kernels, particularly if sold in competition with the larger kernels from Oregon. In the short term when production scale is relatively limited, growers will likely have success with direct sales to customers via farmers markets, CSA, on-farm sales or to retailers with a customer base valuing locally-produced and source-identified foods. At a larger scale of production, the Midwest industry will likely need to add value to the hazelnuts with some sort of processing. Producing oil, flour, confections, and spreads are all possibilities, but will require entrepreneurs with the skills necessary to develop and market branded food products. Large food processing companies might also find smaller kernels preferable for products such as cereals or trail mixes. Selling the smaller kernels as whole kernels to consumers on a large scale might also be possible, but will require aggressive marketing and consumer education. For example, consumers are used to eating handfuls of roasted salted peanuts, why not handfuls of roasted salted hazelnuts?

	St. Paul		Bayfield	
Genotype	**Kernel Wt (g)**	**% Kernel**	**Kernel Wt (g)**	**% Kernel**
HandFats	0.81	42.7	0.53	38.7
Minar342	**0.75**	**38.0**	**0.65**	**31.0**
Rose18-10	0.68	41.9	0.49	36.4
StapN2-7	0.66	39.4	0.38	20.8
SpC-2D5	**0.65**	**37.4**	**0.66**	**35.8**
Rose9-2	**0.62**	**45.5**	**0.45**	**33.0**
PriceW41	**0.58**	**39.4**	**0.51**	**34.4**
StapN7-6	0.56	34.3	0.46	33.4
Gibs5-15	**0.54**	**29.1**	**0.38**	**22.1**
HeasD	0.54	30.3	0.44	27.7
Arb7-21	0.54	36.9	0.41	27.5
StapS2-7	0.54	34.3	0.40	22.6
Arb4-3	**0.50**	**38.5**	**0.39**	**32.9**
Arb7-1	0.49	37.5	0.39	30.3
Gibs6-23	0.49	37.4	0.42	35.9
HeasB	0.48	31.5	0.40	30.9
Cuddy2-28	**0.48**	**35.3**	**0.35**	**32.2**
Eric5-13	**0.47**	**38.5**	**0.31**	**30.4**
GunthPC	0.43	28.9	0.35	27.8
Average	**0.57**	**36.7**	**0.44**	**30.7**
Top 8 Average	**0.57**	**37.7**	**0.46**	**31.5**

Table 2. Five year (St. Paul) and three year (Bayfield) average individual kernel weight and % kernel of 19 top-performing hybrid hazelnuts. Genotypes in bold are the top 8 genotypes based on a combination of yield and kernel quality as selected by Braun et al. (in review). Genotypes are listed in decreasing St. Paul kernel weight.

Per Acre Production Potential

Whether some or any of the eight selections are productive enough to support economically-viable production will depend on a range of variables including the productivity per unit area of the agronomic system in which they are grown and the per pound cost of production of that system. Most woody-perennial specialty crop production systems are utilizing high-density plantings to improve profitability by maximizing

Photo 3. The growth habits of hazelnuts vary by genotype. Some have a spreading form from rhizomatous suckering (left) while others remain compact with little suckering (right). Photo: Lois Braun

fruiting area and early per acre yields. Simply increasing plant density can improve early yields, but can reduce yields long-term due to interplant competition. Minimizing this competition is typically done with a combination of dwarfing rootstock and regular pruning, or as with double-density hazelnut plantings in Oregon, by removing a portion of the plants once the canopy closes. Thus, the per acre production potential of our top genotypes when grown in a more optimized system than the spaced-plant system used in our trials will likely be much higher.

Photo 4. Work is underway to determine optimal plant density to maximize early yields. A 6' in-row plant spacing used in the performance trials leaves wasted space between plants at low fertility sites like Bayfield (top), but might be too close at high-fertility sites like Stoughton (bottom). Photos: Ruth McNair

Plant Density

Research is underway to determine exactly how to optimize per acre yields of our hedgerow system with our select genotypes, and we are pursuing two strategies. First, we have selected genotypes with compact size by selecting for high precocity, annual bearing, and small plant size. With such compact genotypes we anticipate an initial in-row plant spacing of 4 feet and possibly less. Just how large the select genotypes will get remains to be seen and will depend on site fertility, but if competition is severe, every other or every third plant could be removed and a continuous hedgerow still maintained. Of our top genotypes, some have considerable rhizomatous suckering (Photo 3) with a spreading growth habit, while others have little to no suckering (Photo 3) with a compact growth habit. Thus, optimal planting density may vary depending on growth habit and we will be conducting plant density trials to determine the optimal spacing.

Size Management

Once the plants fill the growing space within the hedgerow some form of pruning or mowing will be necessary to control plant size and replace old wood with new wood. One option we are investigating is renewal pruning where a portion of the oldest wood is removed periodically and the younger stems are thinned. Such renewal pruning is common in high-bush blueberries, but is labor intensive and not likely practical except for small plantings. Another option is whole plant coppicing at 8-12 year intervals. Such coppicing is recommended by Rutter et al. (2015), however our preliminary trials with whole plant coppicing have found that it eliminates two years of yield and a plant's response to the coppicing is highly variable and genotype dependent. To avoid losing 2-3 years of yield, we will be investigating a half-plant coppice approach where half of each plant is coppiced periodically. For our suckering genotypes this method would involve using a sickle-bar mower to narrow the hedgerow as is sometimes done with summer pruning in raspberries. In either case, our priority is to develop size management and stem renewal systems that can be implemented mechanically.

Maximizing per acre production will require minimizing non-productive acreage within a planting such as in headlands and row-middles. With over-the-top harvesting little more than a tractor wheel width is needed between rows. However, more space will be needed if using a sickle-bar or other device to maintain the hedgerow width. Another approach to hedgerow hazelnut production would be wide-row spacing as might be used in alley-cropping systems. In such a scenario, the hazelnuts would be one of multiple revenue streams from the alley-cropping system.

	Canopy Width					Yield Density				
Genotype	4	5	6	7	8	4	5	6	7	8
	----------diameter (ft)---------					---------oz kernel/sq ft--------				
SpC-2D5		**2.9**	**4.3**				**0.37**	**0.45**		
Arb 4-3	**1.6**	**2.3**	**3.4**			**0.10**	**0.52**	**0.45**		
Arb 7-21		2.5	2.6				0.11	0.63		
Arb 7-1	2.4	2.8	3.1			0.06	0.56	0.37		
Cuddy 2-28	**2.5**	**3.9**	**4.3**	**4.0**		**0.05**	**0.09**	**0.53**	**0.51**	
Rose 9-2		**4.2**	**5.0**	**5.4**			**0.15**	**0.17**	**0.58**	
Price W41		**3.1**	**4.0**	**4.3**			**0.18**	**0.35**	**0.55**	
Gibs 5-15		**3.5**	**4.1**	**4.5**			**0.01**	**0.19**	**0.31**	
Gibs 6-23		3.5	4.1	4.9			0.27	0.29	0.39	
Stap N7-6		3.4	4.2	4.4			0.23	0.49	0.34	
Stap N2-7	4.9	6.1	6.8	6.0		0.01	0.01	0.07	0.36	
Gunth PC			4.9	5.6	4.9		0.07	0.15	0.23	0.31
Stap S2-7		3.7	4.9	5.6	4.9		0.07	0.15	0.23	0.31
Rose 18-10		3.1	3.4	3.9	3.6		0.05	0.33	0.36	0.88
Heas D	2.2	2.6	3.8	4.3	5.0	0.03	0.09	0.14	0.31	0.28
Minar 342			**3.7**	**4.4**	**4.4**		**0.00**	**0.03**	**0.30**	**0.69**
Hand Fats			3.5	5.3	6.8		0.00	0.16	0.27	0.09
Eric 5-13		**4.1**	**4.2**	**5.0**	**5.2**		**0.02**	**0.09**	**0.29**	**0.55**
Heas B		3.0	2.5	3.3	3.9		0.02	0.30	0.31	0.17
Average	**2.7**	**3.4**	**4.0**	**4.7**	**4.8**	**0.05**	**0.15**	**0.28**	**0.36**	**0.41**

Table 3. Average canopy diameter and yield density by plant age of 19 top-performing hybrid hazelnuts at Bayfield. Genotypes in bold are the top 8 genotypes based on a combination of yield and kernel quality as selected by Braun et al. (in review). Genotypes are listed by age cohort with the most recent entries to the trials starting at the top.

We established the performance trials with a spaced-plant system to give each plant room to grow and our per acre yield extrapolations are based on multiplying the average per plant yields by the plant density. In a hedgerow system using a high initial planting density and size-control practices, such an extrapolation method may not be applicable and will likely underestimate the yield potential of the hedgerow system.

Yield Density

Evaluating the per acre yield potential of our genotypes, if grown and managed in a continuous hedgerow system, is best done with extrapolations of yield density, which is calculated as the ounces of kernel per square foot of canopy coverage with canopy coverage being the cross sectional area of the shrub at its widest diameter. For the yield and enterprise budget projections that follow we will use an initial planting arrangement of 4 feet within-row and 12 feet between-row. By age 7 on fertile and well-managed sites, we anticipate continuous hedgerows that are 6 feet wide with 6 foot open row middles between the hedgerows for a total per acre canopy coverage of 50% or 21,780 ft^2 per acre. Extrapolating the performance of the selections in the trials to per acre yields is then a matter of multiplying the measured yield density by the canopy coverage.

Table 3 shows the average annual yield densities and widths of the top 19 genotypes at Bayfield. At age 7, the average yield density at Bayfield was 0.36 oz/ft^2. At St. Paul it was 0.33 oz/ft^2 (data not shown). Extrapolated to a per acre basis the yields would be 490 and 450 lbs/acre at Bayfield and St. Paul, respectively. Figure 2 plots the actual average annual yield densities of the top 8 genotypes at Bayfield against the target kernel yield density that would be required of the hedges at each age to equal the expected per acre kernel yields at each age in the Oregon tree-based system. For example, at age 7, per acre yields in the Oregon tree-based system are estimated by Miller et al. (2013) at 1100 lbs of in-shell nuts or roughly 500 lbs of kernel. Assuming our hedgerow system at age 7 would have 21,780 ft^2 in canopy coverage, the target yield density of the hedgerows necessary to equal 500 lbs of kernel would be 0.37 oz kernel/ft^2. As Figure 2 shows, the observed average yield density of the top 8 genotypes at age 5 equals the target yield density. By age 7 all the top genotypes have exceeded the target yield density. This indicates that our top genotypes clearly have high enough yield density for commercial hazelnut production, but achieving high enough per acre yields will require higher initial plant densities than the current 6’ x 15’ standard.

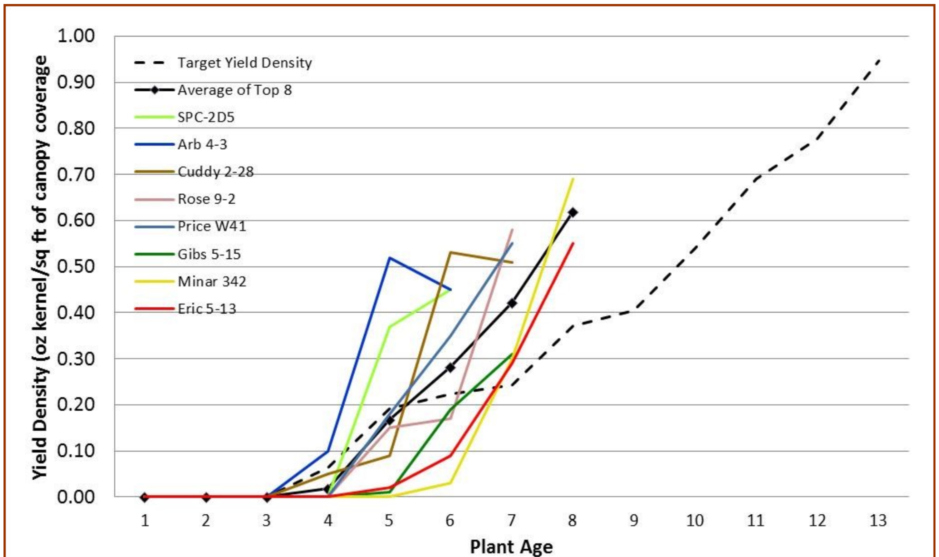

Figure 2. Observed average annual kernel yield density of 8 select genotypes at Bayfield, WI in comparison to the yield density necessary to equal average per acre yields in Oregon tree-based systems.

As the plants continue to age, we expect them to grow taller and wider. It remains to be seen whether yield densities will increase as they grow taller or whether production shifts to the tops of the plants and yield densities stay relatively constant. It will also require further research to determine what effect pruning or other size-management techniques will have on yield density over time. Interestingly, yield densities were higher at Bayfield compared to St. Paul even though total per acre yields were lower. This is due to smaller plants at Bayfield. On such low fertility sites it will likely be necessary to start with higher plant densities meaning a higher initial investment, but with less vigorous plants there may be lower costs for managing plant size compared to the more vigorous sites.

The Economics of Hedgerow Hazelnut Production in the Upper Midwest

An economic model and cash flow projection for 1 acre of hedgerow hazelnut production in the Upper Midwest is presented here. The model includes only cash costs and assumes the operator pays for all expenses out of pocket and owns no equipment. Actual costs will vary considerably from farm-to-farm, particularly as it relates to borrowing, land, and equipment costs. In addition, there remain unanswered questions as to best management practices for hedgerow hazelnut production such as initial planting density, fertilization, pest management, and size management. The assumptions used to build the cash flow model are listed below.

Economic Model Assumptions

Photo 5. Clonal liners in a cold frame being acclimated prior to transplanting. The estimated cost for 1 year clonal liners in 4”x4”x6” pots is \$3.10/plant.

- All labor is hired, hired on a custom-basis, or is provided by the owner/manager as outlined below.
- The owner/manager owns the land, but leases it to his/her hazelnut business at a rate of \$50/ac/yr.
- The site is an average fertility site and the planting is arranged with a 12 foot row spacing and 4 foot plant spacing for a total initial plant density of 908 plants/acre. The plants will fully occupy their space by age 7. Plants cost \$3.10 each.
- Site preparation is done in the summer prior to planting with a burn-down herbicide application, followed by ripping and a finishing disk. The herbicide application is custom-hired at a cost of \$60/acre. The tillage is also custom-hired at a cost of \$180/acre.
- The plants are micropropagated liners in 4 inch x 4 inch x 6 inch pots (Photo 5) and are planted in the fall of the site preparation year between October 1 and October 15. Drip irrigation is installed immediately after planting using a 3/4” mainline, 1 ½” feeder line per row, and two emitters per plant. The water source is a groundwater well with a basic screen filter and manual ball valves to create zones. The total drip irrigation supply cost is \$1.08/plant. No costs for the well, pump, or electricity are included in this budget. Roughly 0.11 yards of wood chip mulch is applied around each plant for a total per acre material cost of \$500/acre.
- Potassium sulfate and triple super phosphate are strip applied and pre-plant incorporated in the summer as necessary to bring phosphorus and potassium soil test levels to 25 and 175 ppm, respectively.
- Planting, application of wood chips, and installation of the drip irrigation system is done on a custom-basis with a crew planting by hand (auger or shovel), and a skid steer to apply wood chips. Total cost for this custom work is \$30/hr or \$840/acre.
- A cover crop is seeded in the spring following planting on a custom basis at a cost of \$150 per acre, which includes seed.
- In-row weeds are controlled in the year after planting with a pre-emergent herbicide applied to the rows with a backpack sprayer. During each successive growing season, grass weeds within the rows are controlled with selective grass herbicides and perennial broadleaf weeds are controlled as necessary with shielded applications of glyphosate using a backpack sprayer. Spot weed whipping is also done to knock down weed escapes.
- Row-middles are mowed as necessary each season with the work hired on a custom basis at \$20/hr which includes the driver and riding-mower. In-row weed control and row-middle mowing costs are \$380/year in years 2-4, \$260/year in years 5-8, and \$240 each year thereafter.
- ESN-protected urea is strip applied each spring at a rate of 80 lbs actual N per acre. Year 0 fertilizer (N, P, K) cost is \$100/acre. Annual nitrogen fertilizer cost each year after is \$56/acre. Hired labor cost of the fertilizer application is \$75/acre/year.
- There is a 3% mortality rate in the year of planting and the plants are replaced in year 2 at a total cost, including replant labor, of \$6/plant.

- All plants begin producing by age 6 with 5%, 50%, and 85% of the plants having produced nuts in the third, fourth, fifth years, respectively.
- Nuts from the planted genotypes average 40% kernel by weight.
- Table 4 shows the projected per plant and per acre yields. By year 10, the plants are fully mature and a biennial yield pattern is established with slightly lower yields every-other-year. Yields at ages 4-8 are based on measured average yields in the trials and yields at age 9-15 are best-guess projections. The age 4-8 yields are calculated based on extrapolating the average yield density of the top 8 genotypes as measured at Bayfield to a per acre and then per plant basis.

Plant Age	Canopy Coverage (sq ft)	oz kernel per sq ft	lbs kernel per acre	lbs kernel per plant	lbs in-shell per plant	lbs in-shell per acre
4	10890	0.02	13	0.01	0.04	**32**
5	14520	0.17	152	0.17	0.42	**380**
6	18150	0.28	320	0.35	0.88	**801**
7	21780	0.42	576	0.63	1.59	**1441**
8	21780	0.62	844	0.93	2.32	**2110**
9	21780	0.66	901	0.99	2.48	**2252**
10	21780	0.72	981	1.08	2.70	**2452**
11	21780	0.85	1162	1.28	3.20	**2906**
12	21780	0.72	981	1.08	2.70	**2452**
13	21780	0.85	1162	1.28	3.20	**2906**
14	21780	0.72	981	1.08	2.70	**2452**
15	21780	0.85	1162	1.28	3.20	**2906**

Table 4. Per acre in-shell nut yields from age 4 through 15. Yields from age 4 through 8 are the average measured yields of the top 8 genotypes at Bayfield. Yields for ages 9-15 are estimated.

- The plants are harvested by hand in years 3, 4, and 5 at a rate of 13 lbs of in-shell per hour. This rate is based on hand-harvesting time trials using tree planting shoulder bags emptied into bins. The hired harvest labor cost is $10/hr. Starting in year 6, the plants are harvested by machine on a custom-basis at a rate of 400 lbs/hr and $80/hr. This is a reported rate by an early-adopter grower using a modified blueberry harvester.
- Renewal pruning begins in year 5, requiring roughly 40 hrs per year of labor to remove old wood and thin existing stems. Some years will require more labor than others. The work is hired at $15/hr.
- Drying is done with forced heated air in pallet crates with periodic turning of the nut clusters to promote rapid drying. A hammer-mill type barrel husker is used to remove the dried husks at a rate of 150 lbs of in-shell nuts per hour. This rate is based on time trials with barrel huskers currently being used by Midwest growers. The husking and drying are done on a custom-basis at a cost of $10/hr.
- No insecticides or fungicide applications are included in this budget, however, it is possible that Japanese beetle, big bud mite, and kernel-feeding insects will eventually require control via an integrated pest management strategy. EFB is managed with plant resistance.
- The project is self-financed with no interest costs.
- The final product sold in this model is in-shell nuts. The nuts are sold to a grower-owned processing company at a price of $2/lb in-shell.

Cash Flow Projections

Table 5 shows the annual cash flow for hedgerow hazelnut production and Figure 3 shows the cumulative net income over the 15 year period. Positive cash flow begins in year 6 when gross revenue exceeds total cash costs, but the break-even point doesn't occur until year 9. For comparison, the cash flow analysis for Oregon hazelnut production by Miller et al. (2013) projects positive cash flow starting in year 5 and a break-even point in year 9. The total working capital necessary to establish and manage the 1-acre planting in the early years is estimated at $8400. The model shown assumes no borrowing or opportunity costs associated with this $8400. The majority of this expense is incurred in the establishment year and is driven largely by plant, drip irrigation, and custom site preparation expenses. Growing crops between the rows in the pre-production years is a good option for improving cash flow. Once the plantings mature, annual net income is estimated at $3400/acre in low yield years and up to $4200/acre in high yield years. As with other woody perennial crops there is significant profit potential for hazelnuts in the Upper Midwest, but the establishment, working capital, and opportunity costs will be an obstacle.

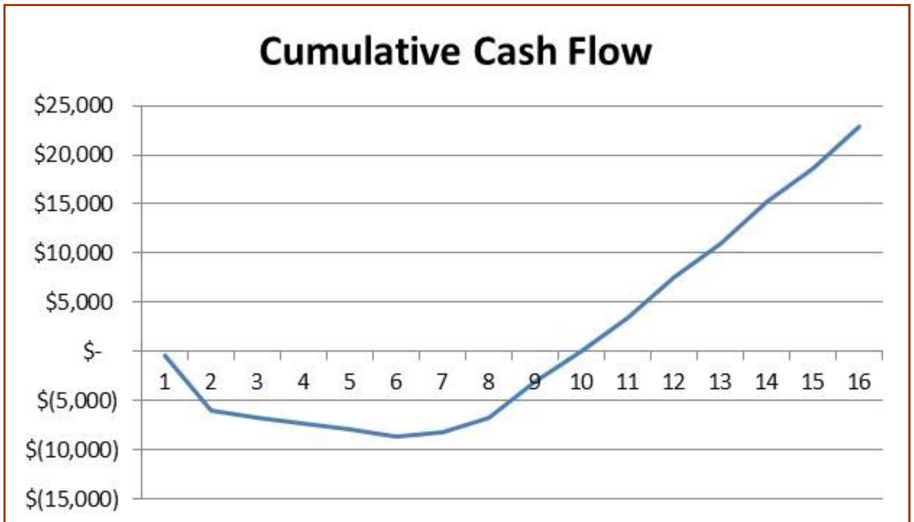

Figure 3. Projected cumulative cash flow for the hedgerow hazelnut system in the Upper Midwest using our first generation select genotypes.

The [Hazelnut Hedgerow Enterprise Budgeting Tool] available at the UMHDI website can be used by growers to build their own budget.

Conclusion

Through our search and screen program, we have identified hybrid hazelnut genotypes, that when grown in a hedgerow-based system modelled after American hazelnut, are capable of supporting commercially-viable hazelnut production in the Upper Midwest. Such viability, however, will depend on growers and marketers having success selling the smaller kernels either through value-added products or by generating consumer acceptance and demand for smaller kernels. As with all woody perennial crops there is a significant up-front investment to establish the hazelnut plantings, but once established and producing, the annual profit potential is significant. More research and development is needed to develop pruning, plant management, and harvesting protocols to maximize per acre nut production from the hedgerows. In addition, with a robust breeding population of *C. americana* and hybrids with *C. avellana* now in place, we have been making controlled crosses and expect second generation genotypes to out-perform these first selections.

Literature Cited

Braun, L., M. Demchik, J. Fischbach, K. Turnquist and A. Kern. Yield, Quality and Genetic Diversity of Hybrid Hazelnut Selections in the Upper Midwest of the USA. Submitted to Agroforestry Systems (in review).

Demchik MD, J. Fischbach, A. Kern, J. Lane, B. McCown, E. Zeldin, and K. Turnquist. 2014. Selection of American hazelnut as a potential oilseed crop. Agroforestry Systems, 88:449-459.

Ercilsi S, Ozturk I, Kara M, Kalkan F, Seker H, Duyar O, Erturk Y (2011) Physical properties of hazelnuts. Int Agrophys 25:115–121

Fischbach, 2010. Wisconsin Hazelnut Growers Survey Report. http://midwesthazelnuts.org/assets/files/2010%20Hazelnut%20Growers%20Survey%20Report.pdf

Fischbach, J., M. Demchik, L. Braun. 2011. Hazelnut production potential in the Upper Midwest: A report on hybrid hazelnut yields. http://www.midwesthazelnuts.org/research.html

Hosseinpour A, Seifi E, Javadi D, Ramezanpour SS, Molnar TJ (2013) Nut and kernel characteristics of twelve hazelnutcultivars grown in Iran. Sci Hortic-Amst 150:410–413

Miller M, Seavert C, Olsen J (2013) Orchard economics: the costs and returns of establishing and producing hazelnuts in the Willamette Valley. Oregon State University Extension Service, AEB 0043.

Molnar, T.J, J.C. Goffreda, C.R Funk. 2005. Developing Hazelnuts for the Eastern United States. Acta Hort. 686

Rutter PA, Wiegrefe S, Rutter-Daywater B (2015) Growing Hybrid Hazelnuts. Chelsea Green Pub, White River Junction, VT.

Rutter M (1991) Variation in resistance to eastern filbert blight in hybrid hazels. Northern Nut Growers Association Proceedings 82:159–162

Shepard, Mark. 2013. Restoration Agriculture. Acres USA. Austin, TX, USA

Weschke, C. 1954. Growing nuts in the north. Webb, St. Paul, MN.

	Establishment		Pre-Production			Early Production				Full Production						
Revenue	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
In-shell nut sales																
Market 1				$ -	$ 36	$ 651	$ 1,605	$ 2,900	$ 4,232	$ 4,514	$ 4,925	$ 5,837	$ 4,925	$ 5,837	$ 4,925	$ 5,837
Market 2				$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Market 3				$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Gross Revenue	**$ -**	**$ -**	**$ -**	**$ -**	**$ 36**	**$ 651**	**$ 1,605**	**$ 2,900**	**$ 4,232**	**$ 4,514**	**$ 4,925**	**$ 5,837**	**$ 4,925**	**$ 5,837**	**$ 4,925**	**$ 5,837**
Expenses																
Land Cost																
Owned	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Rented	$ 50	$ 50	$ 50	$ 50	$ 50	$ 50	$ 50	$ 50	$ 50	$ 50	$ 50	$ 50	$ 50	$ 50	$ 50	$ 50
Supplies and Materials																
Plants	$ -	$ 2,827	$ 164	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Drip Irrigation	$ -	$ 985	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Tree Tubes	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Fertilizer	$ 103	$ -	$ 56	$ 56	$ 56	$ 56	$ 56	$ 56	$ 56	$ 56	$ 56	$ 56	$ 56	$ 56	$ 56	$ 56
Herbicide	$ -	$ 98	$ 58	$ 58	$ 58	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18	$ 18
Organic mulch	$ -	$ 502	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Synthetic mulch		$ -														
Total Supplies and Materials	**$ 103**	**$ 4,412**	**$ 278**	**$ 114**	**$ 114**	**$ 74**	**$ 74**	**$ 74**	**$ 74**	**$ 74**	**$ 74**	**$ 74**	**$ 74**	**$ 74**	**$ 74**	**$ 74**
Custom Equipment and Operator	$ 240	$ 990	$ 380	$ 380	$ 380	$ 260	$ 260	$ 260	$ -	$ 240	$ 240	$ 240	$ 240	$ 240	$ 240	$ 240
General Labor	$ -	$ 150	$ 75	$ 75	$ 75	$ 675	$ 675	$ 675	$ -	$ 675	$ 675	$ 675	$ 675	$ 675	$ 675	$ 675
Custom Harvest Cost				$ -	$ 14	$ 250	$ 161	$ 290	$ 423	$ 451	$ 492	$ 584	$ 492	$ 584	$ 492	$ 584
Drying and Husking				$ -	$ 2	$ 43	$ 107	$ 193	$ 282	$ 328	$ 389	$ 389	$ 328	$ 389	$ 328	$ 389
Total Expenses	**$ 393**	**$ 5,602**	**$ 783**	**$ 619**	**$ 633**	**$ 1,309**	**$ 1,220**	**$ 1,349**	**$ 547**	**$ 1,490**	**$ 1,531**	**$ 1,623**	**$ 1,531**	**$ 1,623**	**$ 1,531**	**$ 1,623**
Annual Cash Flow	**$ (393)**	**$ (5,602)**	**$ (783)**	**$ (619)**	**$ (597)**	**$ (658)**	**$ 386**	**$ 1,551**	**$ 3,685**	**$ 3,024**	**$ 3,393**	**$ 4,214**	**$ 3,393**	**$ 4,214**	**$ 3,393**	**$ 4,214**
Cumulative Cash Flow	**$ (393)**	**$ (5,995)**	**$ (6,778)**	**$ (7,397)**	**$ (7,993)**	**$ (8,652)**	**$ (8,266)**	**$ (6,715)**	**$ (3,030)**	**$ (7)**	**$ 3,387**	**$ 7,601**	**$ 10,994**	**$ 15,208**	**$ 18,602**	**$ 22,816**

Table 5. Cash flow projection for hedgerow hazelnut production in the Upper Midwest.