RUTGERS
New Jersey Agricultural Experiment Station

Thomas J. Molnar, Ph.D.
Associate Professor
Department of Plant Biology
180 Foran Hall
Rutgers, The State University of New Jersey
59 Dudley Road
New Brunswick, NJ 08901-8520 USA

aesop.rutgers.edu/~plantbiopath
molnar@aesop.rutgers.edu

Phone: 1-848-932-6330
Fax: 1-732-932-3844

Rutgers Hazelnut Test Trials 2019: Brief Overview on Production, Orchard Design, and Orchard Establishment

Thomas J. Molnar and John M. Capik
Plant Biology Dept. Rutgers University

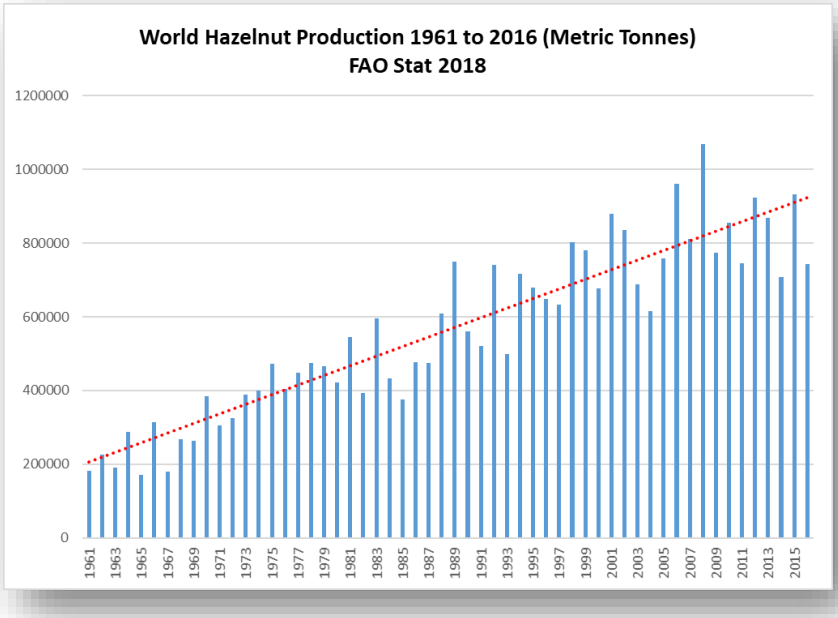
Background on hazelnuts (aka filberts):

Current production centers: Historically, the European hazelnut, *Corylus avellana*, has been grown commercially in regions of the world with Mediterranean-like climates that have mild summers and cool winters moderated by large bodies of water. Today, around 70% of the world's crop comes from the Black Sea slopes of northern Turkey, 15% from Italy, and 5% from the U.S. Smaller amounts are produced in Chile, France, Spain, Georgia, Azerbaijan, and China. Ninety-nine percent of the U.S. crop is grown in the Willamette Valley of Oregon.

World hazelnut market: The international hazelnut market is currently valued at about $3 billion, with total world production averaging about 850,000 metric tonnes per year. Ninety percent of the crop is sold as kernels for confectionary and snack products, whereas only 10% is sold as in-shell nuts for home cracking. Turkey by far dominates the world market, and their round, clean kernels set quality standards for the confectionary industry. Production worldwide has increased steadily over the past 50 years (see below). However, the bi-annual production of the crop, which is quite pronounced in Turkey, affects the world wholesale price each year and prices paid to farmers can fluctuate between $0.80 to nearly 2.00 per pound for dry, in-shell nuts. Oregon generally produces large-sized nuts for the in-shell market, and much of their current production is exported to China. It is important to note that **nearly all hazelnuts consumed domestically are imported!** Demand for hazelnut products continue to rise, especially for products like Nutella® (Ferrero®) with supplies just barely meeting demand.

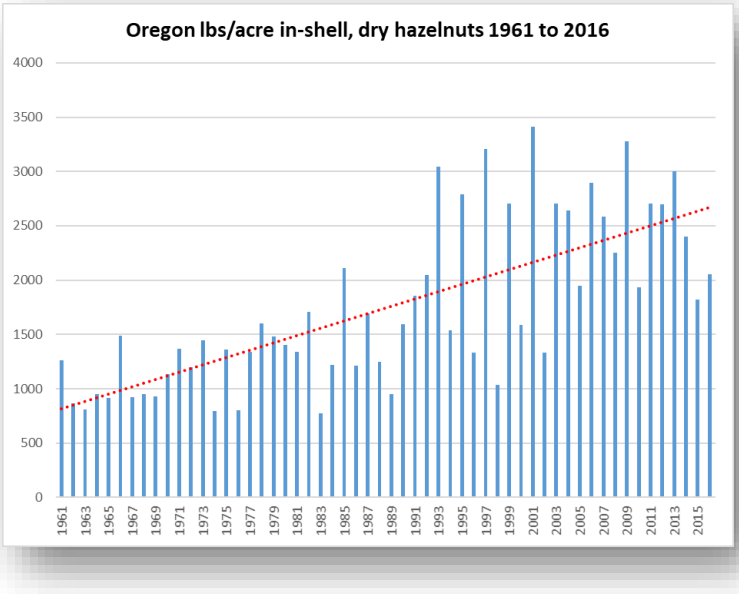
Turkish hazelnut, round and free of skin when roasted

Typical Oregon in-shell hazelnut ('Barcelona')



Production traits: Hazelnut is considered to be a very low-input, yet high-value crop. It can be grown on a variety of soil types (if well drained) and with limited pesticide applications, limited supplemental irrigation (in the northeastern US), and minimal pruning once established. The crop is harvested mechanically (needs much less hand labor than other horticultural crops), and is stable and non-perishable once dried (can be stored over 1 year and still maintain quality). **Follow this link below to read Oregon State University production guidelines and extension bulletins,** which has significant carryover for New Jersey and other parts of the eastern US.
https://www.dropbox.com/sh/5g1vme2o3rycyie/AADd3_OuFuC-ZkxKzP2HYv6Fa?dl=0

Hazelnut yields: Hazelnut production in Oregon reaches some of the highest yields in the world. However, bi-annual bearing is still common. This is largely due to over 80% of the orchards being planted to the cultivar 'Barcelona', which has this genetic tendency. Newer cultivars combined with better management show less bi-annual production. With improved management, yields per acre have increased over the past 20 years in Oregon; the past 10 year average was **2,511 pounds nuts per acre.** "Down" years still remain close to 2,000 pounds.




Eastern filbert blight stem canker

Hazelnuts in the eastern U.S.: Attempts at hazelnut production have been made in the eastern U.S. since colonial times but with no success. This failure is NOT climate related, as the Fruit Belt regions of the East, such as the Mid-Atlantic region, have temperatures and rainfall patterns quite amenable for hazelnut production. **The lack of success is solely related to a naturally occurring fungus, *Anisogramma anomala*,** that causes the disease eastern filbert blight (EFB) on hazelnuts.

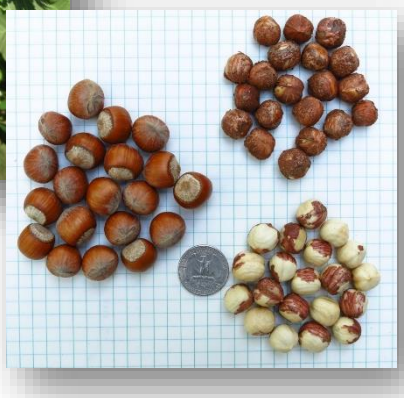
EFB is found associated with the wild American hazelnut, *Corylus americana*, which has a wide native range across eastern North America. EFB causes little damage on the native species, but is devastating to the European hazelnut. Our native

hazelnut, which has tiny, non-commercial quality nuts, acts as a reservoir for the fungus to spread spores that infect the European hazelnut when planted within its range.

EFB in Oregon: For nearly 100 years, the EFB fungus was not found in Oregon or Washington, which allowed the industry to thrive. However, in the 1960s it was introduced through the nursery trade into Washington, where it nearly eliminated production. It quickly spread south and has become a serious expense and management challenge in Oregon. Breeding efforts at Oregon State University led to the release of "resistant" cultivars about 10 years ago. They have been widely adopted and resulted in a significant expansion of acreage (the Oregon industry has expanded ~12,000 ha over the past 8 years). **Unfortunately, the Oregon trees get EFB in New Jersey!**

Rutgers Hazelnut Breeding Program: Rutgers has had an active hazelnut research and breeding program since 1996. The primary objective was to identify resistance to the fungus that causes EFB. The approach to find resistance included making large seed collections across Eastern Europe, the Caucuses, and Central Asia to grow the collected trees in New Jersey. From these populations, about 2% of trees were discovered to have some resistance. These plants and other sources have been incorporated into advanced breeding lines in our program to develop resistant, improved commercial-quality cultivars suitable for planting in the eastern US.

Rutgers breeding nursery showing healthy trees and those dying from eastern filbert blight



Example of new Rutgers hazelnut selection: EFB-resistant and high-yielding with high-quality kernels

Current status - we are very close to releasing new cultivars: We have four advanced selections undergoing micropropagation in labs in Oregon and Ontario. Once they have perfected their techniques, these plants will be patent-protected and licensed for commercial propagation (trees available for sale in nearly unlimited quantities). We hope that these plants will be ready for our first growers in the fall of 2020, but it may take an additional year to build numbers. Regardless, we are planning with interested farmers now to be ready for these trees in 2020.

Preparing for orchard establishment: *Note: Below is a very brief overview of components to consider when growing hazelnut. It should not be considered as a thorough examination, just a primer on various aspects of the crop*. Now is the time to begin preparations for those interested in planting the first commercial test orchards. While the clonal nut producing cultivars won't be available until 2020/2021, some pollenizers are available now and can be planted right away (as described later). Hazelnut is a new crop for the eastern US, and we are still developing best management practices for the region. Fortunately, we can borrow a lot of knowledge from Oregon and Italy. Using experiences gleaned from more traditional regions, and our own efforts at Rutgers, we will work closely with new growers interested in helping us develop this new crop. *First, below are some brief agronomic points to consider.*

Young hazelnut orchard showing clean strips in rows

1) Site selection: *We greatly prefer that the initial test orchards are established on the most appropriate lands*. This is to help us develop a baseline for good tree growth, yields, and nut quality, and to get the early industry off to a great start. Soils appropriate for peaches and apples are usually considered very good for hazelnuts, as is land that has shown success with other horticultural crops and grains. For the most promising results, do not locate a hazelnut orchard where the soil is poorly drained (hazelnuts cannot tolerate "wet feet"), shallow, too heavy, or too light, although irrigation, mulch, and increased fertility can augment the latter. An orchard that is unproductive because of unsuitable soil is generally not profitable. See notes on site selection here https://catalog.extension.oregonstate.edu/em9076

Table 2.—Nitrogen application rates for young hazelnut trees.

Age (year)	Apply this amount of N (lb/tree)
0–2	0
3–5	0.25–0.33
6–7	0.33–0.50
8–10	0.50–0.75

Nitrogen data from Oregon State Extension Service

2) pH and Fertility: Please do a soil test before planting. https://njaes.rutgers.edu/soil-testing-lab/how-to.php An ideal pH is 6.5, but a range of 5.8 to 7.0 is generally fine for hazelnuts (we will base our initial fertility approaches on information from Oregon https://catalog.extension.oregonstate.edu/em9080

Rutgers hazelnut trial at harvest time

3) Weed control and mowing: Hazelnuts are shallow rooted and can suffer from weed competition. Weeds need to be controlled in the tree strips in the row (4-5' wide), typically with labelled herbicides including

contact and pre-emergent chemistries (glyphosate, Surflan®, Goal®, etc.). Mulching (possibly plastic mulch) is also a good option, especially in years prior to nut harvest from the orchard floor (vacuum harvester will suck up mulch). *Organic production may also prove quite amenable for hazelnuts*. Roadways should be planted to grass or other cover crops to prevent erosion, but be mowed regularly to reduce competition.

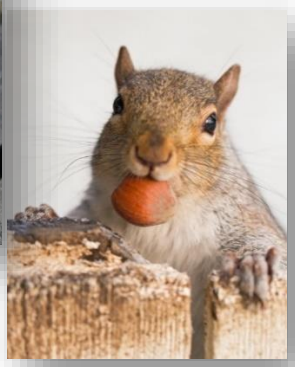
Six-year-old orchard showing proper maintenance

4) Irrigation and new tree planting:
Irrigation can be very beneficial to tree establishment, during the early years, and for boosting kernel quality (kernel fill) during severe droughts in later years. However, it is not a requirement for production in the eastern US. The best time of the year for tree planting is generally the fall (October) with well hardened stock, but spring planting is also possible if water is available. Soak trees in after planting to settle the soil and then, if possible, irrigate over the next 2 years during dry spells. Economics will dictate the need for irrigation in later years—trickle irrigation will likely be a useful addition and will be explored in research trials. Regular irrigation will bring trees into bearing sooner, allow for better yields in dry years, and can reduce the habit of bi-annual bearing, but hazelnuts can be grown without it on good soils (e.g., sandy loam, or any with high soil organic matter) where proper weed control and mowing is practiced. Very sandy soils will likely need irrigation for success, especially once trees reach maturity and crops are produced (year 7-8 from initiation).

Filbert worm, *Melissopus latiferreanus,* present in OR but not yet seen in NJ

5) Pest and disease control: Besides EFB, hazelnuts suffer from few diseases of concern. Some orchards may find bacterial blight is a problem in young trees, but this is typically sporadic and controllable with copper sprays. No other diseases of economic impact are common for hazelnuts, and few insect and mites affect the crop. Most hazelnut-specific pests from Oregon (filbert worm, filbert aphid) are not present in large numbers in the East. However, Japanese beetle can be a problem and require sprays if the numbers get very high. Brown marmorated stink bugs were an issue in the past, but have had a substantially reduced prescence in NJ recently. Big bud mite is here in the East, but seems to occur only in low numbers. It too is easily controlled (dormant oil sprays). Aphids and mites tend not to become a problem due to natural predators. There are no routine or required insecticide/miticide/fungicide sprays for hazelnut, allowing the orchards to be hosts for a diversity of helpful arthropods and other organisms.

Due to limited chemical sprays, hazelnuts can be a safe haven for beneficial insects



Rodents may be the biggest threat to your hazelnut crop

6) Rodent control: Squirrels and chipmunks can DEVESTATE the crop. They eat the nuts directly from the trees in July before they are ready to be harvested and then continue until the crop is gone. **They can eat literally 1,000s of pounds of nuts per acre.** Plant as far from the woodline as possible and encourage hawks and other predators. Hunt, trap, etc. to reduce populations. Ground hogs, mice, rats, blue jays, bears, and turkeys also like to eat hazelnuts.

7) Pruning: Hazelnuts grow naturally as multi-stemmed bushes. However, to enhance early yields and ease of harvest, production trees are to be maintained as single stems, which will require removing suckers from the base 2-3 times a year by hand or with chemicals. In addition, during the first dormant season, select three to five major limbs to become the scaffold branches. Choose limbs that are evenly spaced around the tree trunk in different directions and have some vertical space between them (preferably at least 6 inches). Remove all of the other limbs. Very little pruning is necessary after the scaffold structure has been established. Once canopies close (10-12 years), systematic pruning needs to be done to open canopies to light (remove every other tree if on 10' in row spacing).

Note that the nuts drop to ground at harvest, as well as remnants of suckers at base of crown

Young hazelnut stems are easily damaged by buck rub; plastic fence tubes can greatly reduce this damage

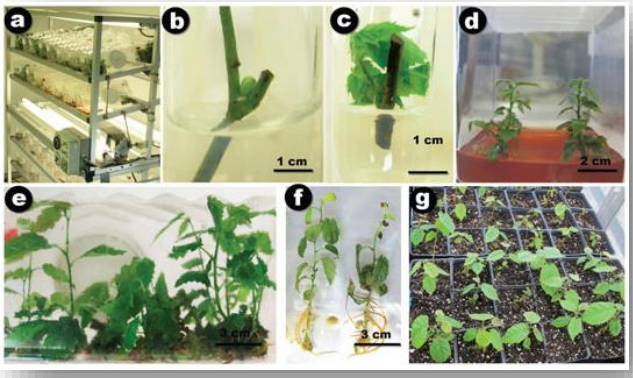
8) Deer Protection: For optimal results, including coming into bearing as soon as possible, trees need protection from deer. Farmland with a secure deer fence is the very best option. Deer will browse on new shoots, which slows growth, and bucks can cause major damage to stems with their antlers. Plastic garden fence can be cut into tubes 4' high and secured around the stem to deter buck rub. Once trees are over 6' tall, deer browse is less of a concern. However, deer may also learn to eat nuts that fall to ground at harvest.

Female flowers (above) and male flowers (right)

7) Plant material—pollenizers: Hazelnuts are a wind-pollinated (no bees needed), self-incompatible species. This means that they require unrelated sources of pollen to produce nuts, and some plants may not be able to interpollinate. Hazelnuts bloom in February and March in New Jersey. Interestingly, male (catkins) and female flowers open at different times of the year, depending on the winter temperatures. This requires a series of early, mid, and late pollenizers, or female bloom of the nut producing cultivar can be missed. Our fluctuating climate can also cause catkins on some trees to elongate too early and become damaged by sub-freezing temperatures. Fortunately, female flowers are extremely cold hardy and stay receptive for multiple weeks. If compatible pollen comes available at some point in the winter after female bloom, crops will be a success.

Seed-derived pollenizers will be distributed from Rutgers for early test trials

Starting in 2019, we are supplying farmers with pollinizer seedlings from selected breeding lines (see details below). To ensure consistently high yields, our current approach is to grow a wide diversity of seed-propagated (not clonal) pollenizers grown in higher density rows in the orchard (border rows, and every 6th row). Utilizing a diversity of seed-based pollenizers is the best opportunity for complete orchard pollination (range of timing, S-alleles, and cold hardiness). Further, planting pollenizers a year or two early will provide time for trees to mature and reduce any lag time in cropping based on an inadequate early supply of pollen. *These produce nuts too, but they will be variable…*



Micropropagation of hazelnuts. Very effective way to multiply thousands of plants in short period of time

8) Plant material—clonal nut producers: Hazelnut cultivars are propagated clonally like apples. However, they are not grafted but produced on their own roots. They cannot be rooted from stem cuttings, thus have been produced through mound layering or more recently by micropropagation (tissue culture). Today, nearly all hazelnut cultivars are propagated by this method, including much of the new orchards being planted in Oregon. **Unfortunately, cultivars developed in Oregon get EFB in the East…**

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High quality hazelnuts peel very easy after roasting…

New cultivars from Rutgers: As mentioned earlier, 6 breeding selections are in the final running for release from Rutgers and will be made available commercially in late 2019. Most likely, 4 of these will be chosen and recommended for larger-scale production based on propagation success and current results from existing yield trials. The first plants will go out to "test farms" for pilot scale (1-2 acre) evaluations prior to wider distribution in 2019. Pollenizer distribution began in 2017 and will continue in 2019. **Test trials are detailed later in this document.** The new EFB-resistant trees produce high-quality, flavorful kernels that fit perfect into confectionary market needs and also can be sold as in-shell nuts or made into a number of tasty, value-added, local products.

Other cultivars or seedlings available? We collaborate very closely with Oregon State University and test plants from their program regularly. While the new Oregon cultivars 'Jefferson', 'Dorris', 'McDonald', and 'Yamhill' produce excellent quality nuts, we have found them to get too much EFB in our plots at Rutgers to recommend. They would need routine fungicide applications to be successful, which some growers might consider acceptable. However, due to the expense of the chemical applications and uncertainty of long-term control in the east, we cannot advocate this approach.

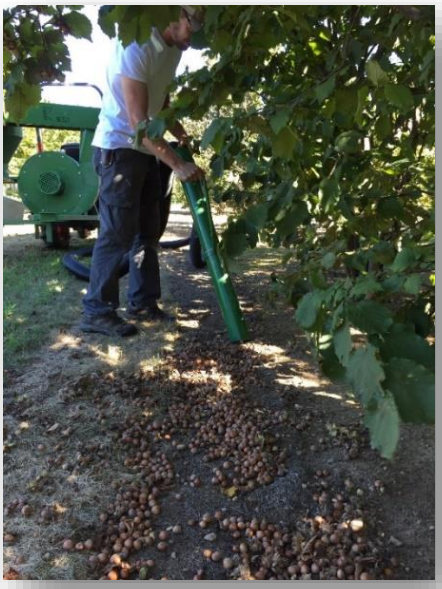
'Yamhill' is widely planted in Oregon where is gets no EFB

Other possible clonal plant material includes cultivars from Grimo Nut Nursery in Ontario Canada, namely 'Gene' and 'Slate', as their best selections available. These trees have shown no EFB in our trials. However, the nut quality is too poor to recommend for those interested in commercial scale production. They might find good utility as backyard garden trees and pollenizers.

Hybrid hazelnuts—small, cold hardy multi-stemmed shrub

Hybrid hazelnuts? These are seed-propagated hazelnuts grown in Upper Midwest derived from crosses of our native hazelnut with the European hazelnut and then allowing the offspring to open pollinate and cross over multiple generations. While EFB resistant and very cold hardy, they are highly variable in most traits and generally have poor nut quality (tiny nuts and poor flavor) when compared to clonally propagated European hazelnuts. On average, kernels are very small, yields are low, and nuts do not drop to the ground for harvest. But they are cold hardy and produce lots of pollen**… They may prove very useful as pollenizers in Mid Atlantic region!**

8) Harvest and cleaning nuts: Hazelnuts naturally drop their nuts to the ground in early September (no shaking required). They are harvested directly from the orchard floor. A variety of machines exist for harvest (available in Italy and Oregon). The most simple machine is an Italian vacuum-type device like pictured here. It is powered by the PTO on a tractor. However, much more sophisticated and efficient machines are available. For collection, nuts are generally blown into windrows (e.g., backpack leaf blower, push-blowers, etc.) and then collected with the machine in a concentrated area. However, this option collects a lot of other debris (as shown below), which must be then cleaned by another machine. More expensive, self-propelled harvesters may have a cleaning stages included.



Harvesting at Rutgers with Italian-made Chianchia model K530 vacuum

Harvester powered by Kubota narrow nursery tractor to fit down tight rows

Debris including sticks, stones, and shells must be cleaned

Italian-made Chianchia two stage cleaner works fast and does an excellent job. It also removes blank nuts. These machines are relatively low cost options suitable for the 10+ acre farm. Many other options exist for larger-scale operations.

Nuts drying at Rutgers in dry greenhouse. Here they take about 2 weeks to complete drying at ambient temperatures.

9) Drying, sorting… cracking. Once harvested and cleaned, hazelnuts need to be dried to around 6% moisture for consumption and long-term storage. This can be done on a small scale in a rain-proof area with good air circulation (onion sacks, stacked boxes with mesh bottoms, or on concrete floor in layers of 2-3 inches of nuts stirred regularly). Drying takes around 2 weeks depending on relative humidity and temperatures. For larger scale operations, heated dryers are used. Once dry, in-shell nuts can be stored at room temperatures (away from odors) for over a year and still maintain quality.

Nuts can be sold in-shell directly to consumers, but most buyers will be interested in kernels. We have not explored the food safety requirements needed to be in place yet at Rutgers for cracking kernels for sale, as this requires working in a certified clean kitchen (project for the near future). However, in preparation for shelling, in-shell nuts need to be sorted by size using round-hole sorters, ideally in 0.5 - 1.0 mm diameter increments. Various machines exist for this process that can be purchased, such as our Italian-made sorter and sheller from the Chianchia company.

Italian-made size sorter and sheller at Rutgers (Chianchia P80 Super).

In-shell nuts stored at Rutgers, dry and in large sacks at ambient indoor temperatures. Quality is stable for 1 year.

Once sorted, the nuts can be cracked by a variety of available devices, some of which also remove the shell pieces. Our small-farm device works quite well, but may not meet all US food safety specifications. We can examine shelling machines used in Oregon to build our processing operations in the East.

Rutgers hazelnuts were selected to have high-quality kernels that should yield premium prices for growers

Kernels: Hazelnuts have a very long storage life when kept in the shell – one year at room temperature and two years in freezer. Dry, raw kernels kept in sealed containers in cold storage remain fresh for 6 months or longer in cold storage and longer in the freezer. However, they should be used soon after thawing. Roasted kernels and crushed or cut/sliced kernels have shortened storage life; roasted nuts have the very best flavor when consumed within a week from roasting.

Value added products: Substantial economic opportunities may exist for developing locally grown and produced, value-added hazelnut products. Demand for hazelnuts are increasing worldwide, especially for products like nut butters (Nutella®), ice creams, and candies, but also for other end uses like healthy nut-based snacks (consumption of tree nuts as a health food continues to rise—see heart healthy claims by FDA), and nut milks and culinary oils. Many options exist for value added product development. Examples include raw and dry roasted nuts, salted nuts, candied nuts, healthy nut butters, chocolate-hazelnuts spreads, ice cream/gelato, chocolate candies, chopped nuts for toppings, nut milks, and gourmet roasted hazelnut oil (consider also "organic" versions of each). Some farmers have experimented with finishing hogs on hazelnuts to enhance meat quality as a value-added component. We hope that our collaborators will come up with some new and exciting ways of utilizing their crops, and let us know all about it!

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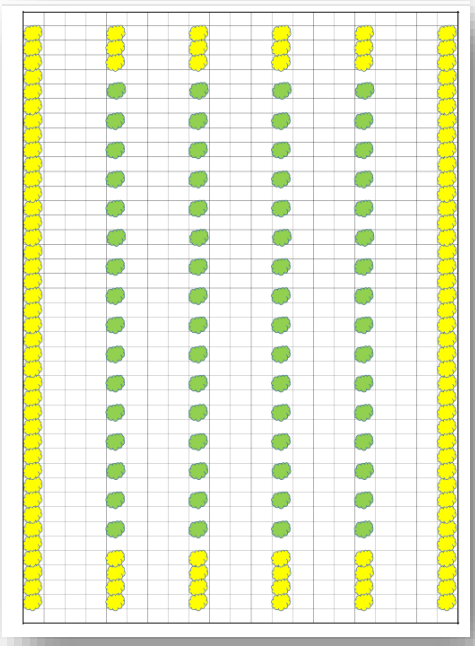
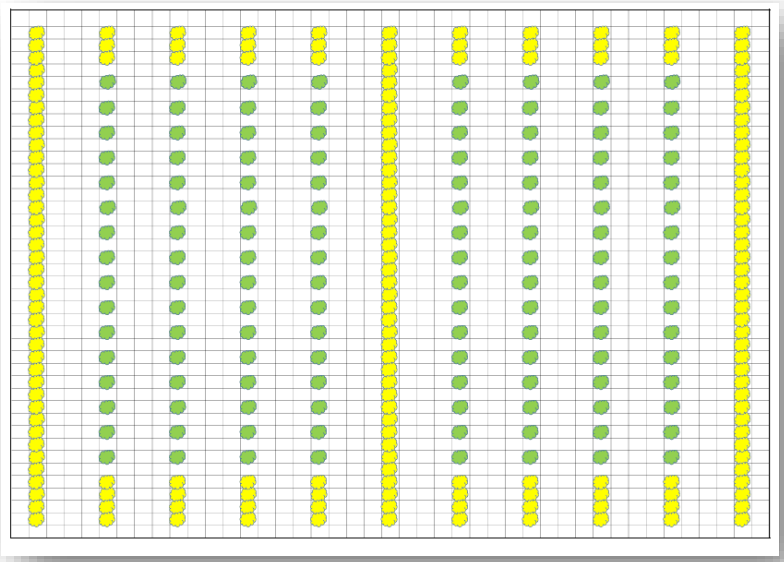
Establishing Rutgers Hazelnut Trials: There are two components to the test orchards – nut producers and pollenizers. Here we describe plans for initiating **small test trials that will require approximately 1/2 acre**. One acre size orchards will have a similar design, just expanded. Larger plots will follow similar design with borders and every 6th row a pollenizer row.



Test-plot mock up for 100' x 200. Each block on the grid is 5' square.

Example: plot of land 100' wide x 200' long (20,000 sq. feet)

- Spacing between rows is 20 feet **(6 total rows)**.
- The outer rows of the trial will be planted to pollenizer seedlings (yellow trees in diagram) spaced at 5 feet apart within the row. **These can be planted this summer/fall (2018)—select seed-propagated trees grown at Rutgers**. This would be around 100 trees per appx. 1/2 acre (we would also start each row with 3-4 seedlings).
- The 4 interior rows of the plot will hold the clonal nut producing trees (green trees on diagram). **These are spaced 10' apart**. These trees should be available to be planted next fall 2019. This would be 64 trees (16 per row) for such a plot. We have 6 experimental varieties. Trees would be planted in a systematic design to aid data collection and evaluation, which would be discussed with individual farmers when the trees become available. Plot sizes can vary, but spacing should be kept similar. Rows can be spaced 18' apart and clonal trees spaced 12' apart to gain a little more time before having to cut trees or prune heavy. 10 foot between trees is considered high density and some trees will need to be removed around year 10 based on practices in Oregon.

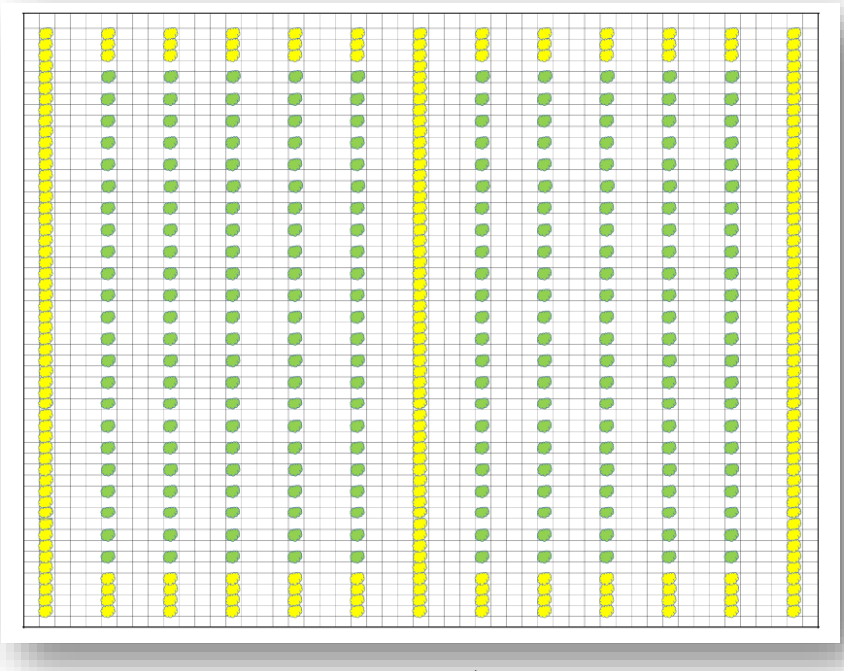


Test-plot mock up for 200' x 200' field layout. Each block on the grid is 5' square. Yellow tree = pollenizer seedling, green tree = clonal nut producer. Test-plots have over abundance of pollenizers to make sure pollen is not a limiting factor.

Example of 1-year old test orchard

Other plot considerations for best results:

- Weeds need to be controlled in the tree strips in the row (4-5' wide) as discussed earlier in the document
- Grass must be mowed regularly within the plot - short grass and few weeds conserves moisture and fertility for the trees.



Larger field design has pollenizers every 6th row. Idea is to not be more than 60' from a pollen source based on research in Oregon. Every sixth row should be pollenizer row. Each block on the grid is 5' square. Yellow tree = pollenizer seedling, green tree = clonal nut producer

- Young trees should be irrigated if possible – if it's not possible to irrigate, all planting is to be done in October/November with dormant stock. The first 2-3 years are very important to get good root growth and support nuts being produced in year 4 onward.
- Trees need protection from deer - especially the clonal trees planted in 2019. Seedling pollenizers can take some deer browse, but it slows down growth greatly and will take longer for them to come into production and produce pollen. Some growers will use individual metal fences around each tree to protect them when the entire farm/plot is not protected by a larger deer fence.
- We would like soil tests to be done on your plot. Rutgers has a soil testing lab which can do the necessary analyses (https://njaes.rutgers.edu/soil-testing-lab/how-to.php), although you are welcome to have it done elsewhere. We can help design a fertility plan based on these results.

Other notes:

- The different clonal trees will pollinate each other, but we found they can be frost damaged in some years (female flowers and vegetative buds are very cold hardy). We are supplementing orchards with a high density of seed-propagated pollenizers to ensure a very large pollen cloud. Research around the world has shown pollen to be a major limiting factor in regions new to production (i.e., Chile, New Zealand, and Australia).

- The seed-propagated pollenizer trees will produce edible nuts, but they will vary in size and shape. They will all taste good when roasted (good hazelnut flavor is fortunately fairly standard). They might be fine mixing with the clonal trees if you have a size sorter, but that depends on the end product, as the clonal trees will have better roasting attributes and be much more uniform in quality. If used for other products (crushed nuts, butters, oils, etc.), there will be almost no difference in utility as long as they can be separated by size. By establishing pollenizer rows in the orchards, it should be possible to blow the clonal nuts into rows away from the pollenizer trees to keep them separate at harvest if desired.

- **We would love a donation of $3.00 per tree to cover costs**. The seedling pollenizer trees are select seed strains from our program, are grown for a full year or more, and are 3-4' tall. The cost for the container and potting mix and fertilizer runs probably $2 per tree alone, not including the labor to maintain them. Comparable purchases from nurseries would typically be at least $10-15.

Thanks from the Rutgers Hazelnut team! Emil Milan (left), Tom Molnar (middle), and John Capik (right)

- **Of great importance** – This is an experimental trial, and your farms will help us decide on the best varieties to release for production. We will need your help in evaluating them for yields, tree health, quality of nuts, etc. What we learn from your trials will help shape the future of hazelnut production in NJ and elsewhere in the East. We will plan on visiting your farms in upcoming years as trees come into maturity to talk to you about what to look for and get your input on how you think the plants are performing. We will always be available to help in any way we can, and any questions or issues should be directed to us as they arise. We have been working on this for over 20 years (!!), and these plantings represent a huge step in our goal of establishing a new industry in the eastern US. If hazelnuts are successfully introduced into the agricultural landscape, it could potentially represent a model system for other new crops to make their way here, potentially helping change the way farmers decide what to grow and promoting a more sustainable, perennial agriculture system. Thank you for your assistance.

Additional Hazelnut Information:

Comprehensive fact sheet on growing hazelnuts in Ontario. Many components are based on Oregon experience and with the expectation they would grow Oregon varieties. However, they have now found they get EFB in Ontario. The industry is exploring some locally developed hybrids and considering chemical management for EFB. Pollination will be a concern in southern Ontario as late cold snaps are common and could damage catkins. http://www.omafra.gov.on.ca/english/crops/facts/12-011.htm