

NITROGEN FERTILIZATION FOR HYBRID HAZELNUTS IN THE UPPER MIDWEST

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ABSTRACT

Hybrid hazelnuts, which combine the high nut production of the European hazelnut, *Corylus avellana*, with the winter hardiness and disease resistance of two native American species, *C. americana* and *C. cornuta*, are being proposed as an alternative crop for the Upper Midwest. However, good agronomic information about growing hybrid hazelnuts in the Midwest is lacking. Current nitrogen (N) recommendations for hazel nut production are based on research from Oregon and may not be applicable to these hybrids in Minnesota due to differing soils, climate, genetics, and growing systems. Anecdotal information from Midwestern growers suggests that these hybrid hazelnuts have very high N requirements, but this had not been confirmed in replicated trials. Excessive N is economically wasteful, may damage the crop, and may become an environmental pollutant, so development of reliable N recommendations will help growers optimize profitability and reduce negative environmental impacts. Field research to determine appropriate N rates was started in 2003 in three new and four established plantations. Preliminary data suggest that N requirements are very low for new plantings, but increase as the bushes grow, and may be very high for mature bearing bushes.

Keywords: *Corylus*, fertilization, filberts, hazelnuts, nitrogen

INTRODUCTION

Hybrid hazelnuts, developed for the Upper Midwest of the US, are a new crop with potential as an alternative to annual row crops. These are hybrids between *Corylus avellana*, the common European hazel, which is the basis for commercial production worldwide, and two species of native American hazels, *Corylus americana*, the common American hazel, and *Corylus cornuta*, the beaked hazel. The two American species confer genetic resistance to Eastern Filbert Blight (EFB), a disease that threatens to decimate the hazelnut industry in the Pacific Northwest, as well as cold hardiness and tolerance to the extreme weather conditions of the Upper Midwest (Rutter and Shepard 2002). Woody perennial crops such as hazelnuts reduce soil erosion, improve soil and water quality, sequester soil carbon, and reduce agricultural energy use at the same time as enhancing wildlife habitat and ecosystem diversity (Josiah 2001). A viable hazelnut industry in the Upper Midwest would help farmers diversify economically while also enhancing ecological sustainability.

Nitrogen is recognized as the most important nutrient for nut crops, both for growth of young seedlings and for sustained nut production. Although hybrid hazels can grow and be productive with little or no N fertilizer, additional N may increase growth and precocity of young plantings, and productivity and profitability of mature plantings. Subjective observations by growers suggest that hybrid hazels are heavy N feeders, but there is currently no empirically derived information to support these claims. Additionally, too much fertilizer at the wrong time may stress young seedlings and excess fertilizer may become a pollutant.

Current N recommendations for mature hazelnuts in Oregon (Olsen 2001) are based on comparing the N content of leaf tissues to optimal levels. Chaplin and Dixon (1979) determined optimal leaf N levels by developing curves of nut yield against leaf N concentration. Recommendations for new plantings are based on soil test N. However, these N recommendations, which are based on research from Oregon and British Columbia, may not be applicable to hybrids bred for Minnesota conditions, due to differing soils, climate, genetics, and growing systems. For example, whereas hazelnuts in Oregon are pruned to be trees, and are grown in open clean-cultivated orchards, Midwest hybrids were bred to be bushes, and to be grown closely spaced in hedgerows, with permanent groundcover between rows. Additionally, whereas hazelnuts in Oregon are transplanted as grafted layers, these hybrids are currently transplanted as very young seedlings.

The objective of this research is to provide growers of hybrid hazelnuts in the Upper Midwest region with empirically derived nitrogen recommendations, to improve the viability of hazelnuts as an alternative crop.

METHODS

New Plantings

Three new plantings were established in May and June 2003 on sites with low soil organic matter in east-central Minnesota (Table 1). Soil P and K levels were amended to moderate levels before planting. Plant material consisted of four genetic lines of two- to three-month old “tubeling” seedlings from Badgersett Research Corporation (Canton, MN) and one line of “Skinner” rooted layers from Grimo Nut Nursery (Niagara-on-the-Lake, Ontario, Canada).

Treatments were N rates of 0, 3, 6, 11, 22, and 33g N plant⁻¹ (0, 11, 23, 45, 91, and 136 kg ha⁻¹), applied as ammonium nitrate in the spring. Fertilizer was broadcast on the soil surface within a 15 cm radius of each plant and incorporated immediately. In 2003, N was applied in July, two weeks after planting was complete; in 2004 it was applied in April/May. Treatments were replicated five times at each site in a randomized complete block, with the five genetic lines nested within N rates. All sites were hoed within rows; perennial ryegrass was planted between rows.

Measurements in 2003 and 2004 included above-ground growth parameters (height, spread, and stem caliper), tissue N content, soil nitrate and winter survival. These measurements will be repeated in 2005. In September 2004 one plant from each treatment at one site was excavated to determine root dry weight and root:shoot ratios; more will be dug in 2005.

Table 1. Characteristics of research sites.

	Year planted	Soil series and texture (soil order)	pH	% organic matter	Weed management
New Plantings					
Becker Sand Plains Research Farm, Sherburne County	2003	Hubbard loamy sand (Entic Hapludolls)	6.7	2.0	Hoed within rows; perennial ryegrass planted between rows is mowed.
Arboretum Horticultural Research Center, Carver County	2003	Hayden loam (Glossic Hapludalfs)	6.3	2.4	
Rosemount UMore Park, Dakota County	2003	Urban land-Waukegan silt-loam complex (disturbed Typic Hapludolls)	6.5	3.0	
Established Plantings					
Fillmore Cooperator's Farm, Fillmore County	1997	Renova silt loam, eroded (Typic Hapludalfs)	6.4	2.4	Dense quackgrass within rows; mowed between rows.
Chippewa Cooperator's Farm, Chippewa County	2000	Tara silty clay loam (Aquic Hapludolls)	6.7	4.8	Completely clean- tilled
Staples Central Lakes Ag Center, Wadena County	2000	Verndale sandy loam (Typic Argiudolls)	6.7	2.0	Woodchip mulch within rows; mowed between rows
Rosemount UMore Park, Dakota County	2000	Waukegan silt loam (Typic Hapludolls)	6.5	4.6	Hoed around plants; clover between rows is mowed.

Established Plantings

In 2003, N trials also were started using the same N rates on four established plantings in Minnesota. Two plantings were on-farm, planted in 1997 and 2000, and two were on experiment station land planted for other research in 2000 (Table 1). Blocking for the established plantings was by previous treatment or genetic line, depending on site, with three to eleven blocks per site. Weed control methods that had been used by previous managers were maintained. Measurements in 2003 and 2004 included aboveground growth parameters (height, spread, stem calipers, and number of stems), tissue N content, soil nitrate, and winter survival. Nut yield data were collected from three of the sites in 2004. Data collection will continue through 2005.

Because these hybrid hazelnuts are multistemmed bushes, response to fertilization may be observed in other ways besides increased height and spread, such as in increased number and caliper of stems. Aboveground dry weight is the ideal measurement, but is destructive, so a biometric was developed to estimate aboveground dry weight from nondestructive measurements. Many different measurements were taken on 20 five-year-old bushes at Badgersett Research Farm, after which they were harvested at ground level, dried, and weighed. Regression analysis was used to determine which parameters best explained the variation in aboveground dry weight. The resulting regression equation was used to estimate dry weight of the plants used in the N trials. Estimates of dry weight from pretreatment measurements in

spring 2003 were compared with dry weight estimates from the fall of 2003 to determine response to fertilization.

PRELIMINARY RESULTS

New Plantings

Soil $\text{NO}_3\text{-N}$, measured two weeks after application in 2003 and again in late summer 2003, was correlated with N application rates (Figure 1). Plant height and stem caliper, measured after leaf drop, did not show an N-rate effect, but there was a dramatic N-rate effect on survival (Figure 2). At least 70% of seedlings on fine-textured soils died with N rates of 22 or 33 g plant^{-1} , and over 40% of seedlings at all sites died with 11 g N plant^{-1} . Mortality was first observed at Becker and the Arboretum two weeks after fertilization, but was not obvious at Rosemount until May the following year. The much larger layers from Grimo Nut Nursery, which had been planted a month earlier, were unaffected by high rates of N, except at Rosemount where they had been stressed at the beginning. By July 2004 there was nearly 50% mortality overall at all sites, but surviving plants were growing vigorously, with few apparent differences between the survivors, though some control bushes had a paler green leaf color. In unreplicated root excavations the plant with 3 g N plant^{-1} had the highest leaf, stem, and root biomass, but the lowest root:shoot ratio.

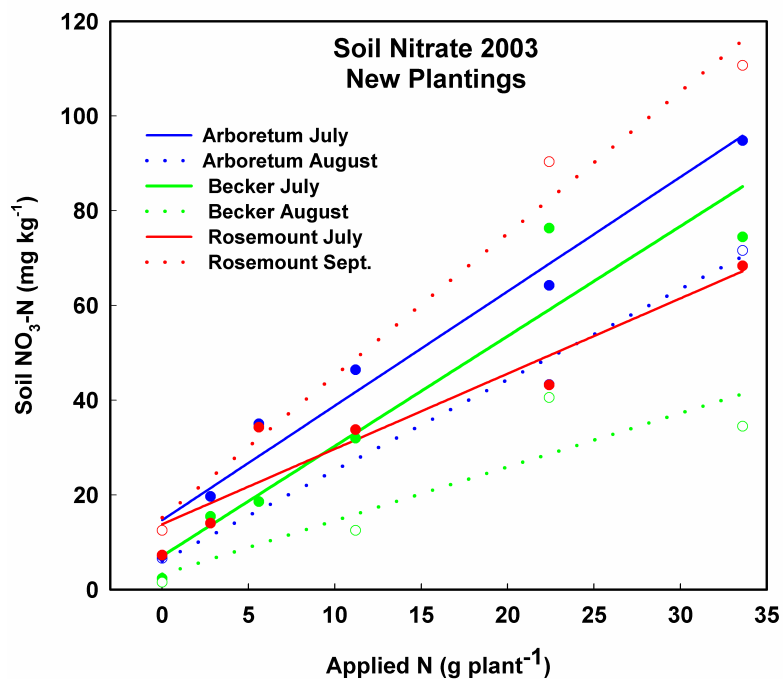


Figure 1. Relationship between fertilizer N and soil nitrate in new plantings, measured two weeks after fertilizer application (July, closed circles, solid lines) and again in August (open circles, dotted lines). Soil nitrate was positively related to applied N at all sites ($R^2 = 0.58$, $p < 0.005$).

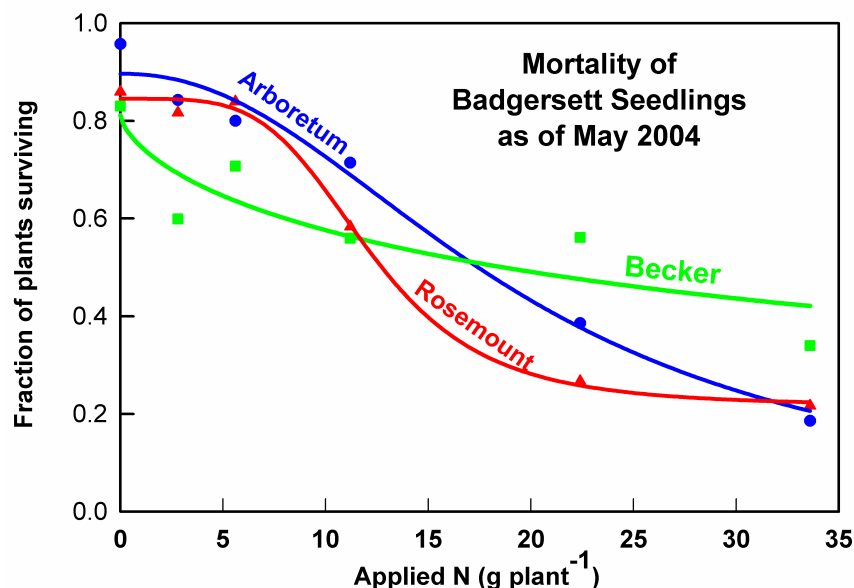


Figure 2 Mortality of Badgersett seedlings at new sites as of May 2004. (Data on Grimo layers is not included.) 1 = 100% survival. 0 = no survival. Mortality was negatively correlated with N rate at all sites at $p < 0.0001$. Mortality at the lowest three rates was independent of N rate, except at the Arboretum.

Established Plantings

Soil nitrate was highly correlated with application rates at all sites except for Staples, where it may have been leached out of the sandy soil by irrigation, or have been immobilized by mulch (Figure 3). Leaf N was highly correlated with applied N at Rosemount and at Staples, but not at the Chippewa County site, where growth was vigorous and leaves were dark green or at the Fillmore County site, where growth was slow and leaves were a paler green color (Figure 4). Only at Rosemount was leaf N correlated with soil nitrate-N. Overall, 2003 leaf N was moderately to severely deficient, as defined by Oregon standards for European hazelnuts.

Regression analysis produced the following biometric to estimate above-ground dry weight ($R^2 = 0.93$):

$$\begin{aligned} \text{g dry matter} &= -223 + 0.000192 \text{ volume in cm}^3 \text{ (calculated as height X average width)} \\ &+ 11.8 \text{ caliper of largest stem in mm} \\ &+ 17.2 \text{ number of stems larger than 5 mm} \end{aligned}$$

No growth response to N was observed at any site after one year, whether measured as change in height, spread, stem caliper, or using the biometric. The only significant predictor of growth was initial size of bush. At the Chippewa County site, estimated dry matter increased an average of 25% across N rates.

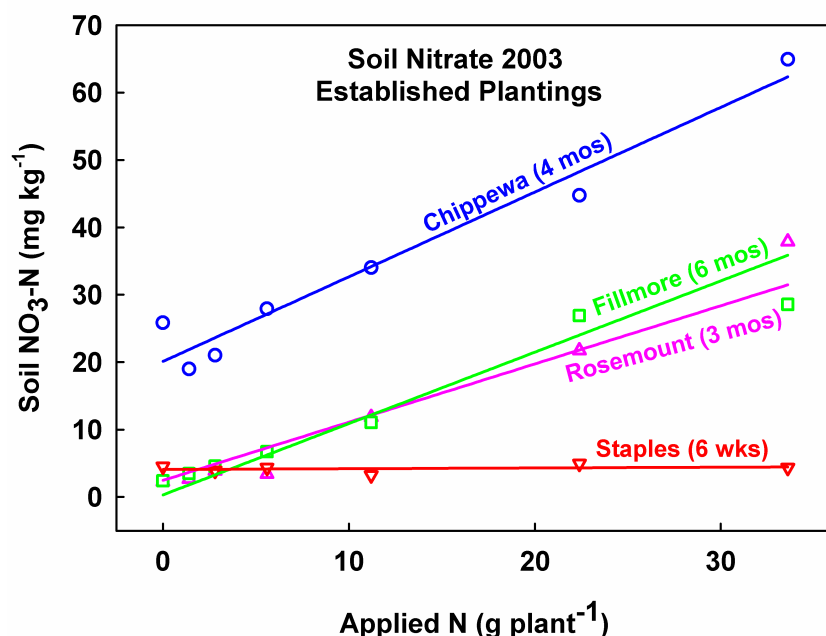


Figure 3. Relationship between fertilizer N and soil nitrate at established hybrid hazelnuts, measured two to six months after N fertilization. Soil nitrate was positively related to applied N at all sites ($R^2 = 0.45$, $p < 0.01$) except Staples.

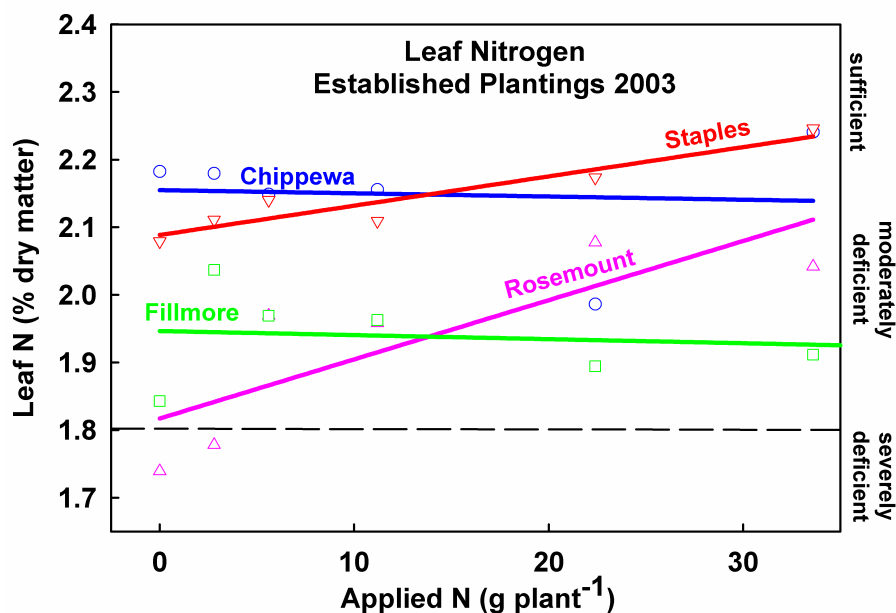


Figure 4. Relationship between fertilizer N and August leaf N concentration (%) in established hybrid hazelnuts. Leaf N was related to applied N only at Staples ($R^2 = 0.52$, $p < 0.02$) and at Rosemount ($R^2 = 0.69$, $p < 0.0002$). According to Oregon standards, samples below the upper dashed line are moderately N deficient; those below the lower dashed line are severely N deficient.

DISCUSSION AND PRELIMINARY CONCLUSIONS

New Plantings

The mortality associated with high fertilizer applications may be related to soil pH or salinity. Soil pH declined with increasing rates of fertilizer, but patterns did not explain the observed mortality. For example, soil pH of low-mortality/control plots at Rosemount was lower than the pH of high N rate/high mortality plots at the other two sites (Table 2). We did not find scientific reports of hybrid hazelnut pH tolerance.

Table 2. Soil pH at new plantings two and six weeks after fertilization in plots receiving 0 and 33 g N plant⁻¹ ammonium nitrate.

	2 weeks after fertilization		6 weeks after fertilization	
	controls	highest rate	controls	highest rate
Arboretum	6.0	5.6	5.9	5.3
Becker	6.1	5.8	6.3	5.2
Rosemount	5.4	5.2	5.2	4.8

A more likely explanation for mortality was osmotic stress resulting from high concentrations of ammonium and nitrate in the soil solution of high N treatments. The two sites with the highest initial mortality, also had the highest levels of soil nitrate initially, whereas at Rosemount, where mortality was delayed, soil nitrate did not rise to high levels until later (Figure 1). This also explains why the larger Grimo transplants, which had a larger root system at transplanting and had an additional month to recover from transplanting, escaped fertilizer injury. These results support the Oregon recommendation to wait until the second year after transplanting to fertilize with N.

Established Plantings

The lack of growth response at any site in the first year was not unexpected because woody plants may store nutrients instead of using them for growth immediately. Two sites, however, showed a response in leaf N concentration, whereas the other two did not, for two different reasons. At the Chippewa site it was likely that N was not limiting in the first place because abundant native N was released from the high organic matter soil with repeated cultivation. Sanchez et al. (1995) warned that plant vigor must be considered when evaluating leaf nutrient concentrations because vigorous growth may dilute leaf nutrient concentrations in a healthy plant. Vigorous growth and healthy leaf color at the Chippewa site support this hypothesis.

At the Fillmore site, where leaves were pale green and growth was slow, it is likely that growth and N uptake were limited by low levels of other nutrients, specifically K and B. These were found to be low in both hazel leaves and soil from this site. Although K is generally considered to be more important for nut quality and yield than for growth of nut crops (Crane and McKay 1955), Kowalenko (1996) found that K deficiency in hazelnuts is common. However, K was just as low at Rosemount, where leaf N correlated positively with both applied N and soil N, suggesting that K deficiency may not have been involved in the lack of response at the Fillmore site. The Fillmore site was the only site with B deficiency; however, we know of no reports of

an effect of soil B on hazelnut growth, although B foliar sprays increase nut set in hazels in some situations (Shrestha et al. 1987).

Another explanation for the lack of N response at the Fillmore site is that quackgrass (*Agropyron repens* L.) competed for N uptake. Although N taken up by quackgrass should eventually be re-released and become available to the hazelnuts, this early intense competition delays hazel maturation, which reduces economic profitability. Samples of the quackgrass have been collected to evaluate this hypothesis. If confirmed, more attention to weed control during establishment may be advisable. Although this would reduce the ecological benefits of managing hazelnuts with companion vegetation, these benefits may still be realized in later years when the hazels are large enough to compete more successfully with this vegetation.

Recommendations for European hazelnuts in Oregon are to apply no N the first year, and to incrementally increase it after that (Olsen 2001). Our tentative conclusion is that this probably is valid for hybrid hazels in the Upper Midwest. However, because the rates that killed these newly planted hazelnut bushes, 11-33 g plant⁻¹, were only one-fifth to one-tenth of the rates recommended in Oregon for two-year-old hazels, we would apply much lower rates than the Oregon recommendations when fertilization is initiated in the second or third year. This is because these hybrid seedlings are much smaller at transplant time than the rooted layers typically used in the Oregon industry and because they grow very slowly in their first year or two.

Because leaf N concentrations in our established plantings were generally lower than the Oregon standards for leaf N (Olsen 2001), with only a few of our samples in the “sufficient” range, we question the validity of the Oregon standards for hybrid hazels in the Upper Midwest. We hope to establish leaf N standards specific to hybrid hazelnuts in the Upper Midwest, by evaluating leaf N concentrations together with growth and yield data. These would form the basis for N recommendations for mature hazelnuts in this region.

ACKNOWLEDGEMENTS

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REFERENCES

- Chaplin, M. H., and A. R. Dixon. 1979. The development of standard ranges for leaf nitrogen in the filbert. *J. Amer. Soc. Hort. Sci.* 104:710-712.
- Crane, H. L., and J. W. McKay. 1951. Preliminary report on growth, flowering, and magnesium deficiency of Reed and Potomac filbert varieties. *Ann. Rep. Northern Nut Growers Assoc.* 42:50-55.

- Josiah, S. J. 2001. Hybrid hazelnuts: An agroforestry opportunity. Lincoln, NE: University of Nebraska, School of Natural Resource Science and Coop Ext. (www.unl.edu/nac/pubs.html#brochures)
- Kowalenko, C. G. 1996. Interpretation of autumn soil tests for hazelnut. *Can. J. Soil Sci.* 76:195-202.
- Olsen, J. 2001. Nutrient management guide--hazelnuts. Oregon State University Extension Service Bulletin EM8786. Available at www.eesc.orst.edu/agcomwebfile/edmat/em8786-e.pdf
- Rutter, P. A., and M. L. Shepard. 2002. Hybrid hazelnut handbook. 1st ed. Canton, MN: Badgersett Research Corporation.
- Sanchez, E. E., H. Khemira, D. Sugar, and T. L. Righetti. 1995. Nitrogen management in orchards. In *Nitrogen fertilization in the environment*, ed., Bacon, P. E., 327-380. New York, NY: Marcel Decker.
- Shrestha, G. K., M. M. Thompson, and T. L. Righetti. 1987. Foliar-applied boron increases fruit set in "Barcelona" hazelnut. *J. Amer. Soc. Hort. Sci.* 112:412-416.

FIGURE CAPTIONS for color figures

Fig.1: Relationship between fertilizer N and soil nitrate in new plantings, measured two weeks after fertilizer application (July, closed circles, solid lines) and again in August (open circles, dotted lines). Soil nitrate was positively related to applied N at all sites ($R^2 = 0.58$, $p < 0.005$).

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FIGURE CAPTIONS for black and white figures

Fig.1: Relationship between fertilizer N and soil nitrate in new plantings, measured two weeks after fertilizer application (July, closed symbols, heavy lines) and again in August (open symbols, lighter lines). Soil nitrate was positively related to applied N at all sites ($R^2 = 0.58$, $p < 0.005$). Symbols are treatment means (Arboretum circles; Becker squares; Rosemount triangles).

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