Journal of the American Pomological Society 72(1): 12-20 2018

Nutrient Status and Fruiting Response of Young Chinese Chestnut Trees Following Application of Nitrogen

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Additional index words: *Castanea mollissima,* growth, nutrients, nut yield, sufficiency range, survey range

Abstract

Development of nitrogen (N) fertilization guidelines for Chinese chestnut trees in North America has been hampered by the paucity of research-based information. Thus, a study was conducted to determine the effect of selected annual N application rates (56, 84, 112, 140, or 168 kg·ha^{-1}) on vegetative growth and fruiting of young 'Peach' Chinese chestnut (*Castanea mollissima* Bl.) trees applied in four sequential years. Foliar N and other macro-and micro-nutrient levels were also determined to establish survey ranges for North American-grown Chinese chestnut. Cumulative nut yield, nut number, and trunk circumference increased linearly as the rate of N increased. Estimated net profitability during three years of nut production increased by 43% when annual N applications were increased from 56 to 168 kg·ha^{-}1. Foliar N of chestnut trees producing the greatest cumulative nut yields during the early years of cropping ranged from 2.23 to 2.51%. The survey range was 0.09 to 0.16% for phosphorous (P) and 0.36 to 0.63% for potassium (K). Macro- and micronutrient survey ranges reported herein from leaves of 'Peach' Chinese chestnut trees provide baseline data for assessing their nutritional status.

Nitrogen is an essential macronutrient for growth and is a constituent of chlorophyll, proteins, and enzymes in plants (Bryson et al., 2014). Because of its importance in plant growth and development, N management is a key factor in chestnut production in commercial orchards (K.L. Hunt, unpublished data). In fruit and nut trees, inadequate N results in poor vegetative growth and restricts yield potential (Westwood, 1993). Alternatively, application of excess N is expensive for producers and can cause excessive vegetative growth and low crop yield due to shading in the tree canopy in subsequent years (Bryson et al., 2014). Nitrogen applied late in the growing season also prolongs vegetative growth, resulting in shoot dieback of chestnut trees following exposure to low temperatures during winter (Warmund, 2008). Additionally, improper N management may result in an environmental hazard when excess nitrate from N fertilizer leaches into groundwater aquifers (Addiscott, 1996).

Since nutrient management is a critical aspect of crop production, nutrient recommendations have been developed for several fruit and nut species. Sufficiency or survey ranges for individual nutrients are routinely used by soil and plant testing facilities as a basis for providing fertilizer recommendations. The sufficiency range, used for foliar testing, indicates the values at which the tissue is at the optimal nutritional status, as determined by field testing (Bryson et al., 2014). When published research data from fertilizer trials are unavailable, survey values are used for recommendations, using nutrient contents obtained from "normal-appearing" tissue or plants with acceptable yield. However, neither sufficiency nor survey ranges have been developed for several specialty crops grown in North America, including Chinese chestnut (*Castanea mollissima*).

Fertilizer recommendations for some nut trees, such as almond, English walnut, and pecan, are based on the strategy of

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replacing nutrients removed from the soil in the harvested crop (Anderson et al., 2006; Doll and DeBuse, 2011; Smith et al., 2012). Additionally, the rate of N recommended is based on a target level of production or yield during alternate bearing cycles. However, annual nutrient removal information is lacking for several perennial nut crops, including Chinese chestnut grown in commercial orchards.

Grafted Chinese chestnut trees generally produce a marketable nut crop three years after planting (Warmund, 2014). Thereafter, fruiting increases annually for at least four years with minimal pruning. Nut yields from mature chestnut trees grown in the United States range from 840 to 2241 $kg \cdot ha^{-1}$ with a retail price of as much as $14/kg (Gold et al., 2006). Based on this range of yield, profitability of chestnut production can be increased by nearly 40% when nut yields are high. However, without proper N management, this increased cropping is unattainable.

Fertilizer recommendations for Chinese chestnut cultivars grown in North America are sparse, limited to a few nutrients, and/or developed using data from other fruit or nut crops (Hunt et al., 2012; Michigan State University, 2015; Olsen, 2000). Thus, the objectives of this study were to: 1) determine the effect of selected application rates of N on the vegetative growth and nut yield of Chinese chestnut trees; 2) assay foliar N in fruiting and non-fruiting shoots; and 3) evaluate foliar P, K, calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn), and molybdenum (Mo) contents to establish survey ranges for a fruiting orchard.

Materials and Methods

Nuts were harvested in Sept. 2006 from 'AU-Cropper' Chinese chestnut trees planted in a repository in 1996 at the Horticulture and Agroforestry Research Center (HARC), New Franklin, MO to produce seedling rootstocks. Immediately after harvest, chestnuts were sealed in polyethylene bags and placed in cold storage at 5 ºC. On 15 Mar. 2007, these chestnuts were sown in 35 x 35 x 13-cm (depth) flats using an 8 pine bark: 4 perlite: 2 sphagnum peat moss: 1 vermiculite: 1 sand (v/v) medium amended with 2 kg Osmocote 13N-5.7P-10.8K, 1.5 kg Nitroform Blue Chip 38N-0P-0K (AgrEvo, Wilmington, DE), and 1.7 kg Micromax micronutrients (Scotts Co., Marysville, OH) per m^3. Seedlings were then transplanted on 1 May 2007 into 11.4-L polyethylene containers (PF800; Nursery Supply, Chambersburg, PA) using the medium previously described. Potted seedlings were grown outdoors under natural conditions in a nursery area at HARC under 55% shade cloth (DeWitt Group, Sikeston, MO) with supplemental irrigation as needed. On 25 Nov. 2007, potted seedlings were covered with a polyethylene foam blanket for winter protection.

Before planting chestnut trees on 30 Mar. 2009, a soil sample (10 cores, 0-15 cm-depth) representing the entire test site, was obtained and analyzed at the University of Missouri (MU) Soil and Plant Testing Laboratory using standard methods (Nathan et al., 2012). Another composite sample (9 cores, 0-15 cm-depth) was obtained on 15 July 2015 at 1.2 m from each 'Peach' chestnut tree trunk in plots where trees received 112 $kg \cdot ha^{-1}$ N from 2012 to 2015. Soil samples were analyzed for soil organic matter by loss-on-ignition; pH in salt solution; extractable P using the Bray-1 method; Ca, Mg and K by ammonium acetate extraction; Zn and Fe by diethylenetriamine-penta-acetic acid (DPTA) extraction; and B by hot water extraction as described by Nathan et al. (2012).

On 23 March 2008, 'Peach' and 'Qing' (used as a pollinizer) Chinese chestnut scions were whip-and tongue grafted onto AU-Cropper seedling rootstocks at 8 cm above the potting medium surface. Grafted tissue was tied with a rubber budding band, sealed with wrapping film (Parafilm M, Bemis North America, Oshkosh, WI), covered with aluminum foil, and placed in a greenhouse at

27 °C day/21 °C night on a 12 h cycle for 3 weeks with natural lighting. Aluminum foil and budding bands were removed and grafted plants were placed in the field nursery and maintained until planting as described above. On 1 Apr. 2009, grafted chestnut trees were planted at HARC at a 4 x 8 m spacing with a 'Qing' pollinizer trees placed between no more than four 'Peach' trees in each row. This site is flat with a deep, upland Menfro silt loam (fine-silty, mixed, superactive, mesic typic hapludalfs) soil. The sod cover crop (75% turf-type fescue/25% Kentucky bluegrass blend) was established in 2007. In April 2009, 2010, and 2011, NH_4NO_3 was applied to the soil surface under the dripline of trees at 14.1, 28.2 and 42.3 $kg{\cdot}ha^{-1}$, respectively. In 2012, 2013, 2014, and 2015, split applications (50:50) of five different N rates (56, 84, 112, 140, and 168 $kg{\cdot}ha^{-1}$ as annual rates), using NH_4NO_3, were applied to the soil surface under trees on Apr. 1 and June 15. Nine, single-tree replications of each N treatment were applied to 'Peach' tree plots in a randomized complete block design. 'Qing' trees used as pollinizers received 112 $kg{\cdot}ha^{-1}$ N annually from 2012 to 2015. Trees were pruned minimally and grown without irrigation throughout this study. Weed control and pest management followed local recommendations (Hunt et al., 2012). Mean trunk circumference (measured at 15 cm above the graft union) of chestnut trees was 14.1 cm on 1 Apr. 2012 when different rates of N were first applied. Thereafter, trunk circumference was evaluated annually in early Dec. Primary nut number and nut weight were also recorded annually in Sept. Late-ripening, unmarketable secondary nuts were not harvested.

Leaves were collected annually on 15 July from 2013 to 2015 [i.e., optimum time of collection (Cao et al., 2009; Toprak and Seferoğlu, 2013)] from sun-exposed non-fruiting shoots to assess foliar N, P, K, Ca, Mg, S, B, Fe, Cu, Mn, Mo, and Zn. Foliar samples were also collected similarly on 15 July 2014 from fruiting shoots to assay macro- and micronutrients. For each tree, five, fully-expanded mid-shoot leaves from fruiting and non-fruiting shoots growing in full sun were collected. Leaves were washed in 1% (v/v) Liqui-Nox anionic detergent (AlcoNox Inc., White Plains, NY), rinsed in distilled water, and oven-dried at 65 °C. Dried tissues were then ground to pass through a 425-μm screen and submitted to the MU Soil and Plant Testing Laboratory. Tissues were analyzed for total N using an automated ion analyzer (QuickChem 8500; Lachat Instruments, Loveland, CO) and for other macro-and micronutrients using inductively coupled plasma optical emission spectroscopy (Varian Vista MPX Simultaneous ICP-OES; Varian Inc., Palo Alto, CA) (Nathan and Sun, 2006). Annual terminal shoot growth of five fruiting shoots located equidistantly around each tree at 1.8 m above the soil surface was measured on 1 Nov. 2015. Annual nut yield and cumulative nut data were subjected to analysis of variance (ANOVA) using the GLIMMIX procedure of SAS (version 9.4; SAS Institute, Cary, N.C.). Means were separated by Fisher's protected least significant difference test at $P \leq 0.05$. Trunk circumference, shoot growth, and cumulative nut number and weight, and annual foliar nutrient content data (2012 to 2015) were also subjected to ANOVA. Orthogonal contrasts were performed to evaluate linear and quadratic responses to varying N rates. Ranges of foliar nutrients are presented to indicate the survey values for leaves sampled from non-fruiting shoots.

Results

Results from soil testing before planting (2009) indicated a 6.1 pH, 2.2% organic matter content, 10.5 meq/100 g cation exchange capacity, and most other elements at medium to high levels (Table 1). By 2015, pH and organic matter content was 6.0 and 2.3%, respectively, in soil samples from plots receiving 112 $kg{\cdot}ha^{-1}$ N from 2012 to 2015. Phosphorus content decreased, K and Zn increased, and other elements varied slightly during the study.

Table 1. Nutrient contents of soil samples from the 'Peach' Chinese chestnut orchard site near New Franklin, MO in March 2009 and July 2015.[z]

	P	K	Ca	Fe	Mg	Bo	Zn
	----------------------(kg·ha^{-1})--------------------------					--------(mg·kg^{-1})---------	
2009	81	461	2923	52	343	0.11	2.7
2015	76	510	2936	50	345	0.11	3.0

[z] Nutrient contents were determined using the methods described by Nathan and Stecker (1999). One composite sample was obtained for the entire site in 2009. One composite sample was obtained 1.2 m from the chestnut tree trunk in plots receiving annual applications of 112 kg·ha^{-1} N from 2012 to 2015.

Chestnut trees began bearing a few nuts in 2012 (≤ 0.5 kg/tree) and trees averaged ≤ 1.3 kg nuts/tree in 2013, but yields did not differ among N treatments (data not shown). By 2014, trees receiving 140 or 168 kg·ha^{-1} N had greater nut yields than those receiving 56 or 84 kg·ha^{-1} N (Table 2). A similar increase in nut production occurred in 2015, although yields among N treatments differed statistically at $P \leq 0.067$. Trees receiving either of the two highest rates of N had greater cumulative nut yield and higher nut numbers in 2015 than those treated with the two lower rates, indicating a linear response to the fertilizer (Table 2). Mean nut weights from 2012 to 2015 were similar among N treatments, ranging from 15.2 to 16.8 g. Terminal shoot growth was also similar among treatments, but trunk circumference increased linearly with increasing rates of N (Table 2).

When foliar analysis was conducted in 2014, the only nutrient that varied by shoot type (fruiting vs. non-fruiting) was N (data not shown). Leaves from non-fruiting shoots had a higher N content (2.17%) than those

Table 2. Reproductive and vegetative characteristics of 'Peach' Chinese chestnut trees following the application of selected rates of N in an orchard planted near New Franklin, MO in 2009.[z]

Annual	2014	2015	Cumulative (2012-2015)			2015	
N rate (kg·ha^{-1})	Nut yield/tree (kg)	Nut yield/tree (kg)	Nut yield (kg/tree)	Total nut no.	Average nut wt. (g)	Current season shoot growth (cm)[y]	Increase in trunk circ. (cm)[x]
56	1.1	2.9	5.0	306	16.8	26.3	18.1
84	1.2	2.8	5.1	311	16.3	27.4	19.6
112	1.4	3.8	6.0	380	15.7	27.0	20.2
140	1.6	4.3	7.3	464	15.7	26.9	21.3
168	1.7	4.4	7.4	483	15.2	26.5	22.4
Significance level[w]	0.0182	0.0668	0.0181	0.0173	0.5211	0.5328	0.0202
Rate linear[v]	0.0010	0.0058	0.0012	0.0010	0.4027	0.5572	0.0009
Rate quadratic[v]	0.7268	0.9869	0.6694	0.7199	0.1873	0.1972	0.9157

[z] Only primary nuts were harvested. Values represent the mean of 9 replications of each treatment.
[y] Annual terminal shoot growth was recorded on non-fruiting shoots.
[x] Mean increase in trunk circumference from April 2012 to December 2015.
[w] P values for ANOVA.

from fruiting shoots (1.97%, $P = 0.001$). In 2013, 2014, and 2015, non-fruiting shoots from trees receiving annual rates of 56 kg·ha^{-1} N had lower N contents in leaves than those of trees receiving the three highest rates of soil-applied N (Table 3). Foliar N had a quadratic response to increasing rates of soil-applied N in 2013, changing to a linear response in 2014 and 2015.

When other macro- and micronutrient contents of leaves from non-bearing shoots were subjected to ANOVA, there were no statistical differences among trees receiving selected rates of N in 2013, 2014, or 2015 for any of the elements (data not shown). Ranges of foliar macro- and micronutrients from non-fruiting shoots receiving 140 or 168 kg·ha^{-1} N are presented in Table 4.

Discussion

After three years of applying selected rates of N, annual chestnut yields increased linearly when trees were treated with increasing rates of N and trees generally had a similar annual yield response in 2015 (Table 2). This delayed yield response to annual application rates of N may be attributed to the lack of precocity and low bearing potential of young chestnut trees. Results from this study were similar to an earlier one in which there were relatively low nut yields of Chinese chestnut trees until the sixth year after planting (Warmund, 2014). Average nut weights from 2012 to 2015 among all N treatments were statistically similar, but were numerically lower when higher rates of N were applied, which was likely due to increased crop load. Like the nut yield response, trunk growth was greatest when trees were treated with N at 140 or 168 kg·ha^{-1}.

A soil sample obtained before planting in 2009 indicated that all elements tested were in the medium to high range of nutrients, according to recommendations used for other fruit crops in Missouri (in the absence of research-based information for chestnut) (Nathan and Stecker, 1999). By 2015, slight differences were noted in soil nutrients tested, but because only one soil sample was obtained from the orchard site in 2009 and

Table 3. Percent N in foliage from non-fruiting shoots of 'Peach' Chinese chestnut trees annually treated with selected rates of N in 2013, 2014, and 2015.[z]

Annual N rate (kg·ha^{-1})	Foliar N content (% dry wt.) 2013	2014	2015
56	2.17	2.05	2.13
84	2.33	2.11	2.29
112	2.44	2.17	2.33
140	2.47	2.23	2.43
168	2.46	2.28	2.51
Significance level[y]	0.0462	0.0011	0.0024
Rate linear[x]	0.1972	0.0010	<0.0001
Rate quadratic[x]	0.0240	0.7268	0.6954

[z] Values represent the mean of 9 replications of each treatment. .
[y] *P* values for ANOVA.
[x] *P* values for orthogonal contrasts performed to test the linear and quadratic responses of different N rates.

Table 4. Survey range of foliar nutrients from non-bearing shoots of ‘Peach’ Chinese chestnut trees treated with annual rates of 140 or 168 kg·ha^{-1} N in 2013, 2014 and 2015 in Missouri and survey range from Hebei province, China.

Site	N	P	K	Ca	Mg	S	B	Fe	Cu	Mn	Mo	Zn
	(%)						µg·g^{-1}					
MO[z]	2.18 to 2.77	0.11 to 0.16	0.46 to 0.63	0.82 to 2.20	0.23 to 0.51	0.20 to 0.21	50.2 to 58.2	168 to179	7.90 to 9.50	570 to 1312	1.24 to 1.47	17.4 to 34.2
Hebei[y]	1.83 to 2.17	0.12 to 0.14	0.51 to 0.63	1.18 to 1.41	0.60 to 0.75	---[x]	35.5 to 51.3	610 to 762	11.22 to 14.23	462 to 725	---[x]	---[x]

[z] Nutrient contents were determined using the methods described by Nathan and Sun (2006). Values represent the range of foliar nutrient contents from trees receiving annual soil-applied N applications of 140 and 168 kg·ha^{-1} in Missouri.
[y] Survey ranges from ‘Zaofeng’ Chinese chestnut trees reported by Guo et al. (2014).
[x] Values not reported.

another one from plots receiving 112 kg·ha^{-1} N in 2015, these slight differences may be due to variability in sampling. However, use of NH_4NO_3 fertilizer is known to lower soil pH due to microbial activity (Bryson et al., 2014). Glyphosate use also affects microbial diversity and activity when applied to agronomic crops, resulting in reduced plant availability of K, Fe, and Mn (Bryson et al., 2014). While glyphosate was applied three times per year in a 1.8 m band beneath chestnut trees in this study, the consequence of these herbicide treatments on soil and chestnut tree nutrition is unknown.

Soil test results in 2015 also indicated that P content decreased during this study even though visible plant symptoms of a P deficiency were not apparent. This loss of soil P may be attributed to plant uptake during the study. Phosphorous loss from erosion was unlikely due to the perennial ground cover and flat terrain at this site.

Potassium content in the soil increased during the study, which might be attributed to soil moisture conditions at the time of sampling, differences in time and areas tested, or other unidentified conditions. Although interactions of K with N, Ca, and Mg have been documented on some crops, much less is known about the optimal ratio of these nutrients in soils or plant tissue for specialty crops (Bierman and Rosen, 2013). Soil tests results obtained in this study indicate that the nutrient status may have changed during the testing period, however, they do not reflect their availability to the trees. Soil testing is generally done before planting to estimate organic matter content, pH, cation exchange capacity, and nutrient toxicity or imbalances in orchards, but it has limited usefulness in diagnosing nutritional problems and predicting crop potential (Smith et al., 2012).

Nutrient cycling in *Castanea* plantings has been reported, but results from high-yielding orchard systems with improved cultivars are limited (Rhoades, 2007; USDA, 2016; USDA, 2017). Nutrient concentrations of leaf litter collected from 20 to 65-year-old American chestnut [*Castanea dentata* (Marshall) Borkh.] trees, growing in a fine silt loam or a sandy loam soil were ≈ 12 g·kg^{-1} N,15 to 16 g·kg^{-1} Ca,1 g·kg^{-1} P, 2 to 3 g·kg^{-1} K, and 3 g·kg^{-1} Mg (Rhoades, 2007). Phosphorous, K, Ca, and Mg contents reported for nutritional labeling of Chinese chestnuts are 96, 447, 18, and 84 mg·100 g^{-1}, respectively, from Chinese chestnut trees (USDA, 2016). Using the USDA NRCS crop nutrient tool

(USDA, 2017) and 2015 Chinese chestnut yield data at the annual N rate of 168 kg·ha^{-1}, the annual loss of N, P, and K was 9.3, 1.3, and 6.2 kg·ha^{-1}, respectively.

Like other nut trees, annual N loss in a managed chestnut orchard likely occurs from harvested fruit (nuts and burs), leaf litter, pruning wood, aborted reproductive organs, and root turnover (Weinbaum and Van Kessel, 1998), respectively. Due to the difficulty of applying isotope-labeled fertilizer and analysis of annual and excavated tree biomass, information regarding uptake and internal cycling of nutrients in Chinese chestnut is limited. For English walnut, 123 kg·ha^{-1} of N was removed from fruit, prunings, and leaves of mature trees annually in California (Weinbaum and Van Kessel, 1998). Also, about 50% of the N within walnut trees was replaced annually and approximately 50% of the total N content of the perennial parts of the tree was available for recycling. Based on Weinbaum and Van Kessel's (1998) findings, recommendations for annual N fertilizer on English walnut grown in California are 168 to 224 kg·ha^{-1} (Beede, 2010), indicating that the highest N rate applied to six-year-old chestnut trees in this study may not be excessive.

In the current study, foliar N was lower in fruiting shoots compared with non-fruiting shoots. This is likely explained by the additional demand for this nutrient by developing nuts and burs. Although current season growth of both fruiting and non-fruiting shoots was not evaluated in this study, those lacking fruit in sun-exposed areas of the tree canopy usually produce more growth than fruiting shoots (M.R. Warmund, unpublished data).

Chestnut trees averaged 2.38% and 2.41% foliar N in 2013 to 2015 when an annual application of 140 or 168 kg·ha^{-1} of soil-applied N was applied and a nut yield response was recorded (Table 3). The linear response of increased nut yield with increasing rates of N fertilizer may indicate that even higher yields may be achieved with higher rates of fertilizer (Table 2). Based upon yields recorded in this study, 2.4% foliar N may be useful as a target value in maximizing nut yield in young Chinese chestnut orchards.

When 180 European chestnut (*Castanea sativa* Mill) trees were sampled in July from 30 orchards in Turkey, average foliar N, P, K, Ca, and Mg contents were 2.81, 0.18, 2.18, 0.30, and 0.48%, respectively (Toprak and Seferoǧu, 2013). Phosphorous and Mg values reported for European chestnut were near those reported in the survey range for current study. However, the foliar content of K was higher than that found in Missouri. Guo et al. (2014) reported the survey ranges of various foliar nutrients for 'Zaofeng' Chinese chestnut trees growing in Hebei province, China listed in Table 4. Relative to survey ranges reported in Missouri, N and Bo were lower and Mg, Fe, and Cu ranges were higher in China (Table 4). Li et al. (2014) reported the need for increased Mg fertilizer to maintain nut yields for eight to 30 year-old 'Zaofeng' trees.

Based on the foliar K content for European chestnut (2.1 to 2.2%) (Toprak and Seferoǧu, 2013), and other nut trees, this nutrient may have been deficient in Missouri-grown trees (0.5 to 0.6%) since K was not applied annually during the study. Sufficient foliar K ranges are considered to be > 1.2% for English walnut (Beede, 2010), 1.0 to 2.5% for pecan (Smith et al., 2012), and 1.4 to 2% for almond (Doll and DeBuse, 2011). Foliar Ca in the present study was also higher than that reported in Turkey, but is not inconsistent with survey ranges for Chinese chestnut values from China (Guo et al. 2014), almond (Doll and DeBuse, 2011), or pecan (Smith et al., 2012).

In conclusion, this study demonstrated a Chinese chestnut yield response to increasing rates of N fertilization when applied to young trees. Substantial gains in nut yield were found in six-year-old trees treated with a split application of N at 140 or 168 kg·ha^{-1} annually for four years. Cumulative net profit for trees receiving 56, 84, 112,140 or 168 kg·ha^{-1} annually for four years with the cumulative yields recorded in this study were $14,920, $14,897, $17,514, $21,306, or $21,576/ ha, respectively, assuming a fertilizer cost of $313.98/t, $10/h labor cost using a manual harvest tool (Nut Wizard, Douglas GA), and a selling price of $10/kg for chestnuts (Warmund, et al., 2012). At the two highest N application rates, mean foliar N ranged from 2.23 to 2.51%. In the absence of established sufficiency ranges for Chinese chestnut obtained from multiple cultivars, survey ranges for macronutrients and several micronutrients presented here will provide baseline data for assessing the nutritional status of North American-grown Chinese chestnut in future studies.

Acknowledgements

Funding was provided by grants from the Center for Agroforestry and the Missouri Department of Agriculture Specialty Crop Block Grant Program. The author gratefully acknowledges Mark Coggeshall for grafting trees for this study.

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Journal of the American Pomological Society

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Reports on field studies are expected to contain data from multiple years. Reports are to be the result of adequately replicated trials and the data should be subjected to appropriate statistical analysis. Manuscripts submitted for publication in the Journal must not have been previously published, and submission implies no concurrent submission elsewhere.

Scientific names and authorities for plants, disease organisms, and insects should be included parenthetically when the organism is first mentioned. American spelling conventions and SI units should be used. Manuscripts should be double spaced throughout. Typical organization is as follows: Title, Authors, Abstract, Introduction, Materials and Methods, Results, Discussion, Literature Cited, Tables, Figures. The Results and Discussion sections are often combined. Author addresses, email adresses and acknowledgements are in footnotes on the first page. More detailed instructions for manuscript preparation can be found at: http://www.americanpomological.org/journal/journal.instructions.html

Before submission, manuscripts should be reviewed by at least two colleagues and revised accordingly. At the time of submission, the corresponding author must attest in the covering letter to the Editor that all coauthors on the paper have had the opportunity to review it before to submission, that it has not been published previously, and that it is not presently under consideration for publication elsewhere. In addition, the names and full contact information (mailing address, e-mail and telephone numbers) for three potential reviewers should be provided. Submit manuscripts electronically to the Editor: Dr. Richard Marini, 203 Tyson Building, Department of Plant Science, University Park, PA 16802-4200 USA; E-mail: richmarini1@ gmail.com. Acceptable format is MSWord.

Manuscripts are sent to two reviewers competent to evaluate scientific content. Acceptance for publication depends upon the combined judgement of the two reviewers and the Editor. In unusual circumstances the Editor, without further review, may return a manuscript, which obviously does not meet Journal standards, to the author.

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