SURVIVAL AND GROWTH OF AMERICAN CHESTNUT *(Castanea dentata* (Marsh.) Borkh.) SEEDLINGS UNDER VARIOUS SILVICULTURAL REGIMES IN A MIXED OAK FOREST ECOSYSTEM

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The American chestnut (*Castanea dentata* (Marsh.) Borkh.) was once an important tree species in the eastern United States. Following the devastating effect of the chestnut blight in the early 1900s, this species has been virtually extirpated from the overstory of the eastern deciduous forest. To facilitate the return of this species to its natural place in the overstory, The American Chestnut Foundation will soon release seeds that contain genetic material responsible for blight resistance, but preserve the genetic heritage of the American chestnut. However, the necessary requirements for site selection, site preparation, and competition control are not well understood for this species and will be essential if restoration efforts are to be successful. The goal of this study was to address these concerns and examine the effects of survival and growth of chestnut within a diverse forest management regime. Seedlings were experimentally grown in three mixed oak forests subjected to thinning, burning, a thin+burn treatment and an untreated control. Overall plant biomass between years 2002 and 2003 differed significantly among treatments for all aspects of plant growth in the thin and thin+burn treatments. As expected, there was a significant increase in light availability in the thinned treatments, and this produced a noticeable effect on seedling growth rates. A more detailed multiple regression analysis revealed a

significant relationship ($P < 0.05$) in 2002 and 2003 between light and most biomass parameters. Soil magnesium, nitrate, potassium, and sand were also significantly correlated ($P < 0.05$) to chestnut biomass. Thus, site fertility should also be considered in reintroduction efforts. While site quality may influence growth, light conditions seem overwhelmingly important. Therefore, we recommend that American chestnut seeds be planted in areas with moderate to high light conditions (recently disturbed), with low surrounding competing vegetation (possibly after a burn) for optimal growth benefits.

Approved

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Introduction

The American chestnut, *Castanea dentata* Marsh. (Borkh.), was an important forest species throughout the eastern United States for the last several millennia (Delcourt & Delcourt 1998). Chestnut was the leading dominant hardwood in some forests, often comprising more than 50% of the basal area of these stands (Braun 1950). When chestnut blight (*Cryphonectria parasitica*) was introduced in 1904 on a cargo shipment in New York, it spread rapidly throughout the oak-chestnut and mixed mesophytic forests of the eastern United States (Merkle 1906; Harlow 1996). By 1940, the blight had reached virtually every forested area throughout the Appalachian region, devastating mature chestnuts in these stands. By 1953, the Oak-Chestnut Association was dropped as a viable vegetation type in the eastern United States (Keever 1953).

Historically, American chestnuts preferred an upland habitat composed of acidic and well-drained sandy soils in mixed forests (Stephenson et. al. 1991). Russell (1987) conducted a post blight analysis of chestnut in Virginia forests and believes that chestnut was abundant on sub-mesic or sub-xeric sites. Throughout most of its range, chestnut routinely reached 24-30 m in height and 0.6-1.2 m in diameter (Woods and Shanks 1959). Trees of old-growth forests may have grown considerably larger. Historically, chestnut trees reproduced by root sprout and rarely through seed because of intensive predation and frost damage to nuts (Pinchot 1905; Paillet 2002). Sprouts have been shown to be a leading competitor after clear-cutting in open canopies, possibly due to chestnut having a strong positive response to high light conditions as compared to other hardwoods

(Boring et al. 1981; Griffin 1989; Latham 1992). Billo (1998) also found that canopy disturbance initiated rapid growth in chestnut seedlings. However, McNab (2003) reported that chestnut sprout seedlings were out-competed in clearcuts by intense sprouting of other species. This suggests that thinning and burning would have a positive effect on chestnut sprouting and survival because the combined effect would create canopy gaps, kill off competitors, and let newly formed chestnut sprouts grow with less competition (Russell 1987).

Since *C. parasitica* is a phloem pathogen which does not affect roots, chestnut sprouts still occur throughout most of its native range. However, these sprouts rarely grow into the mid-story and rarely reach sexual maturity because blight will eventually girdle the stem and kill older chestnut saplings (Paillet 1988). Although *C. dentata* is still important in the understory of many forest systems, it has been rendered functionally extinct as a canopy tree (Parker 1992). If chestnut saplings did not die of blight infection, they probably would out-compete other species and fill newly opened canopy gaps (Paillet 1982).

Three major areas of research have focused on the restoration of American chestnut: the propagation of hypovirulence strains of *C. parasitica*, blight resistant pure American chestnut intercrosses, and the hybridization of Chinese and American chestnuts. A strain of *Cryphonectria parasitica* was first identified on European chestnuts and had been parasitized by a virus (Anagnostakis 2000). This hypovirulent strain was thought to be successful in treating the virulent *Cryphonectria parasitica* on trees by slowing the blight enough for infected trees to recover on their own and survive (Anagnostakis

2000). The primary difficulty has been the slow dissemination of the hypovirus to trees infected with the fungus (Double and Macdonald 2002). The method of breeding resistance from pure American chestnuts hasn't been effective because there are so few naturally resistant trees and those that are available lose some resistance when crossed with susceptible parents to maintain diversity. Hybridization of the blight resistant Chinese chestnut (*Castanea mollissima* Blume) and the blight susceptible American chestnut (*Castanea dentata*) has been another approach to breeding blight resistant American chestnuts. The American Chestnut Foundation (TACF) has now produced a tree through a series of intercrosses that has the genetic material responsible for blight resistance and preserves the genetic heritage of the American species (Hebard 2001). Hybrids were chosen for their resistance and form characteristics, and then backcrossed with other American chestnuts, making them 15/16th pure American chestnut (Burnham 1981). TACF has been performing these intercrosses since 1989 and will be ready for planting the final progeny from them by 2005 (Hebard 2001). The hybrids are showing considerable hope for successful reintroduction.

As preparation for the release of blight-release seeds begin, more needs to be known about the microsite conditions most conducive to chestnut establishment and growth (Phares 1978) in order to maximize the success of chestnut restoration efforts. In fact, because the blight occurred before the advent of modern ecological methods (Paillet 2002), very little is known about even the most basic silvicultural characteristics of *C. dentata*. It is also important to focus on microenvironmental features because these are the most important factors contributing to a plant's existence and growth (Geiger 1950). Therefore, the overall objective of this work was to characterize and quantify silvicultural characteristics most conducive to chestnut success. We examined two specific questions: (1) What silvicultural treatments typically used in the mixed oak forest landscape have the greatest effect on chestnut growth? (2) What environmental factors (e.g., light and soil characteristics) best account for these patterns of chestnut growth? Both questions are being addressed in a diverse management regime and will ultimately provide proper management tools for reintroduction of hybridized seeds?

Study sites

The USDA Forest Service Fire and Fire Surrogate (FFS) research project (http://www.fs.fed.us/ffs) is one of the largest restoration experiments in the continental United States. The Ohio Hills sites were chosen to represent the entire central hardwoods region and are located in Zaleski State Forest, Tar Hollow State Forest, and Raccoon Ecological Management Area.

Experimental Design

The FFS study sites provided the reintroduction trials with a pre-existing field experiment infrastructure that offers a variety of environmental and silvicultural treatments to study American chestnut. Each forest contains a control (undisturbed) and three treatments (ca. 20 ha each): burned (prescribed burn in 2000), thinned (30% shelterwood cut), and a thin+burn treatment (combined 30% shelterwood cut followed by a prescribed burn in 2000). At each of the twelve forest × treatment combinations, there exist ten 0.1 ha vegetation test plots (120 plots total). 2 x 5 m plots were delineated 15 m from the ten vegetation plots located in each forest x treatment combination. Within those plots, 10 American chestnut seeds were planted one meter apart, for at total of 1200 seeds (Figure 1).

Field methods

Fifteen-hundred pure American chestnut seeds were collected from a natural remnant stand of American chestnut in southwestern Wisconsin. Seeds were then stratified in cold storage for 16 weeks at 5 C to mimic forest conditions (Young and Young 1992). They were stored in drainable flats containing a base of peat moss potting mix, saturated with water, and covered to retain soil moisture. Seeds were planted in the spring of 2002 under predator-proof wire cages to monitor germination, establishment, and subsequent growth.

Predator proof cages were constructed out of aluminum gutter screening (C.H. Kieffer, *personal communication*). Cages were 15 cm in diameter and 30 cm in height and were capable of protecting seeds from fossorial and surface predators (Barnett 1998; Bendfeldt et. al. 2001). Each cage was placed in a 5 cm deep hole and held in place with 2.5 cm of soil. The seed was placed in the cage and covered with 2.5 cm of soil (Anagnostakis 1997). A wire flag was weaved into the seam of the cage, holding the cage together and to the ground. The top of the cage was crimped when the seeds were planted and uncrimped when the seedling approached the top of the cage (C.H. Kieffer, *personal communication*). A numbered aluminum tag was attached to the cage for identification.

Fifty percent of each plot's germinated seedlings were harvested from each test plot in September 2002 (because all seeds did not germinate, *N* = 257) leaving 50% of the remaining germinated seedlings in each plot for the 2003 harvest (total survival in 2003 was, *N* = 288). Protocols for seedling biomass allocation follow Robison and McCarthy (1999). Seedlings were dug up and washed with water to remove soil from root tissue. Separated stems and roots were sealed in plastic bags, placed in a cooler, and brought to the laboratory where stem, primary root lengths, and basal diameter were immediately measured. The stems, roots, and leaves were placed in a drying oven at 80 C and weighed after 72 h. Leaves were harvested from all surviving seedlings in September of 2002 (*N* = 579 plants) and 2003 (*N* = 288 plants), kept in coolers in the field, and brought back to the lab for leaf area measurement (Li-Cor, Lincoln, NE). Specific leaf area was determined by coring a 0.01cm^2 disc from each healthy leaf, drying the disc in the oven at 80 C and weighed after 48 h. American chestnut seedlings were given a health rating of one through four at the end of each growing season. A rating of one was given for a healthy seeding and a four if it was defoliated. Germination was recorded in July of 2002 and calculated as percentage. Survival was recorded in September 2002 and again in September 2003 and recorded as a percentage.

The available light at each site was measured by use of hemispherical photography. A 35mm Nikon digital camera with a Sigma 8 mm fish-eye lens was used to take photographs one meter from the ground. Photographs were taken in mid July 2003 at the center of all American chestnut plots. Percent open sky relative to canopy cover and global radiation was determined through use of digitally analyzed images using Gap Light Analyzer software (Robison and McCarthy 1999; Frazer et. al. 2001).

Soil parameters were measured in order to determine their effects on plant growth. Soil collection, processing, and extractive methods all follow McCarthy (1997). One soil sample was taken from the A horizon at each of the American chestnut plots (*N* = 120), placed in a cooler, dried at room temperature, ground through a 2 mm brass sieve, and stored at room temperature (McCarthy 1997). Phosphorus, magnesium, and calcium in the soil were determined for each sample via Mechlich III extraction and atomic absorption spectrometer methods (McCarthy 1997 and Varian 1989). Potassium was determined using a Mechlich III extraction then analyzed using colorimetric spectrophotometry (McCarthy 1997). Nitrate was measured using ion exchange resins that measure long-term nitrate availability in soil (Binkley & Matson 1983; Binkley & Hart 1989; Hart & Firestone 1989). Resin bags that contained 50 g wet weight of ion-exchange resin were placed in the A horizon from June 2003 to August 2003 (Rexyn 300 (H-OH), Fisher Scientific, Fair Lawn, NJ). Nitrate was extracted with 2M KCl solution and analyzed colorimetrically on a spectrophotometer (Spectronic 20D, Unicam, Rochester, NY) using Nitrate Reagent Powder Pillows (Nitra Ver, Hach, Loveland, CO). Soil texture was calculated using the hydrometer method to determine the percent of sand, silt, and clay (Sheldrick & Wang 1993). Soil moisture was calculated from soil texture results (Saxton et. al. 1986). Soil pH was calculated with the glass electrode method using 2:1 water to soil mixture (pH/Ion Analyzer 350, Corning Inc.). Organic matter and ash content were determined using the dry-ash method (Shepard et. al. 1993).

Statistical Analysis

Our experimental design was such that forest was treated as a random effect (block) and treatment was a fixed effect in all analyses. Germination data were analyzed using a General Linear Model Analysis of Variance (GLM ANOVA) using percent germinated seedlings per plot (Zar 1999). Survivorship data were analyzed for year 2002 and 2003 separately using a GLM ANOVA with percent survivors per plot. Health ratings were analyzed using the same GLM ANOVA model. All data were transformed to meet the D'Agostino Omnibus test for normality and pass the Modified Levene Equal Variance test.

Silvicultural treatment influences on American chestnut biomass data were analyzed using a Multivariate Analysis of Variance (MANOVA) followed by GLM ANOVAs to determine differences in years and treatments (Scheiner 1993) for total biomass, basal diameter, stem height, root length, leaf area, specific leaf area, and leaf, stem, root, and fine root mass. Forest was treated as a random effect and treatment and year were fixed effects in both models. Bonferroni post hoc analyses were used to assess differences among the two years and four treatments. All 2002 and 2003 biomass parameters were $\log_{10}$ transformed to smooth data and pass normality, but in using this transformation, data did not entirely pass the homoscedasticity assumption. However, because of the robustness of the MANOVA (Zar 1999) and as it is useful to $\log_{10}$ transform biomass data (McCune and Grace 2002), the MANOVA was performed using only this transformation.

The impacts of microenvironmental parameters such as light and soil nutrients on American chestnut biomass parameters were analyzed using multiple regression (Philippi 1993). Each plot's biomass parameters were calculated separately by using means to compare to each plot's environmental factors (light and soil measurements). Environmental factors were the independent variables and biomass parameters were the dependent variables. Data were screened for multicollinearity and transformed to pass assumptions of normality. All analyses were performed using NCSS (Hintze 2000).

Results

As a consequence of the thin and thin+burn silvicultural treatments applied to forests, results showed that there was a statistically significant difference in light availability among treatments ($F = 27.15$, $P < 0.001$). Treatments that were subjected to thinning had more available light in American chestnut plots than treatments that were not, as in the control and burn treatments (Figure 2).

The 2002 harvest (1 year old seedlings) revealed that thinning and burning had a large effect on plant biomass variables. Plants grown in burn treatments were significantly larger than the control treatments in most leaf parameters ($P < 0.05$). Plants that were grown in the thin and thin+burn treatments were larger in almost all aspects than those grown in the control and burn treatments alone except for specific leaf area where it was significantly smaller in the thin+burn treatments (Figures 3 & 4d).

The 2003 harvest (2 year old seedlings) continued to reveal that the thinning and burning treatments affected plant biomass significantly. Plants grown in the thin+burn treatments were significantly larger in all aspects of growth than those grown in the control and burn treatments except for specific leaf area (Figure 4d) which was significantly smaller ($P < 0.05$). In stem (Figures 3ab) and root (Figures 4cd) variables the thin treatments were significantly larger than the control and burn treatments. In leaf biomass variables (leaf area, leaf mass, and number of leaves) there was no significant difference between the burn and thin treatments, but there was an increase in leaf biomass in the thin and thin+burn treatments (Figures 4a-d).

Overall plant biomass between years 2002 and 2003 differed significantly ($P < 0.05$) among treatments with all aspects of plant growth in the thin and thin+burn treatments being larger than in the control and burn treatments (Table 1). Exceptions included: specific leaf area (Figure 4d), which decreased significantly from the control, burn, thin, and thin+burn treatments, and root length (Figure 3b) where there was no significant difference between the control and burn treatments. These results demonstrate that as the plants grew older, the silvicultural treatment had an increased effect on plant growth in the thin and thin+burn treatments (Figures 3a-f & 4a-d).

Although silvicultural treatment was shown to have a significant impact on biomass variables, germination ($F = 0.44$, $P = 0.09$), survival ($F = 0.56$, $P = 0.11$), and health ratings ($F = 2.13$, $P = 0.19$) did not differ significantly among silvicultural treatments (Table 2).

Out of the environmental variables measured, (light, calcium, magnesium, nitrate, potassium, phosphorus, organic matter, soil moisture, and soil texture) light was most strongly correlated to biomass parameters in years 2002 and 2003 in the multiple regression model. The regression model revealed a significant positive correlation ($P < 0.05$) in 2002 between light and almost all biomass parameters (Table 3). In 2003 this trend continued with light showing a significant positive correlation ($P < 0.05$) between all biomass parameters (Table 3). These results were expected, due to an increase in biomass in the thin and thin+burn treatments where there was also more light availability.

The multiple regression model also revealed significant positive correlations ($P < 0.05$) between several soil parameters and biomass parameters (Table 3). In 2002 nitrate was positively correlated to stem and root variables as well as specific leaf area and in 2003, continued to be positively correlated with root variables. In 2003, magnesium was positively correlated to leaf variables and root mass. Potassium was positively correlated to basal diameter in 2002 and then to specific leaf area in 2003. In 2002, sand had a positive correlation to specific leaf area, but had a negative correlation to stem mass.

Discussion

American chestnut has been cited to be both a broad generalist and a strong competitor (Latham 1992). In our study, chestnut seedlings responded to only certain environmental variables very strongly. Seedlings had a significant positive response to light, as was the case in other studies (King 2003; Boring et. al. 1981). However, because germination, health, and mortality were similar in areas of low light and high light, seedlings showed their best ability to germinate and survive in low light levels (control and burn treatments) and grow rapidly when light then became available (thin and thin+burn treatments). Chestnut seedlings also responded to decreased light by increasing their specific leaf area. This characteristic allows *C. dentata* to survive in a shaded environment. King (2003) also found that specific leaf area increased in *C. dentata* saplings with decreased light. American chestnuts have survived the blight with similar responses to light, by using their ability to survive in the understory of forests and then releasing when light becomes available through canopy gaps (Paillet 2002). Chestnut seedlings in our study were not subjected to canopy gaps after being planted in low light levels, but did show an increase in biomass in areas with greater light conditions. The evidence suggests that *C. dentata*'s general response to light is that of an intermediate shade tolerant species—it has the ability to survive in a shaded environment and the ability to release when exposed to increased light levels.

American chestnut seedling growth was maximized under the highest light environment, which was created by thinning followed by prescribed burning. Boring et al. (1981) showed that chestnuts grew well in clearcuts. In contrast, McNab (2003) reported that chestnut sprout seedlings were getting outcompeted in clearcuts by intense sprouting of other species. Although there are conflicting results on the effects of clearcutting and chestnut, it is known that forest burning is an effective means by which to reduce vegetative competition that occurs after clear cutting (Rieske 2001). This may be why there was an increase in many biomass parameters in year 2003 in the burn vs. control silvicultural treatments. However, the combined thin+burn treatments produced an environment with increased light and limited competing vegetation. These combined silvicultural treatments, as compared to the thin treatments, produced chestnuts with increased biomass that maximized chestnut growth. This is most likely due to adequate sunlight from thinning and competition control from burning, allowing chestnut to develop and release, as noted in work conducted by Perry (2003).

American chestnut was also responsive to a number of soil parameters such as magnesium, potassium, nitrogen, and texture. Magnesium was positively correlated to leaf mass, leaf area, and root mass. This might be due to the central role of magnesium as it refers to chlorophyll construction (Shaul 2002). American chestnut seedlings in our study also showed that as potassium increased, so did basal diameter and specific leaf area. Such a response might be because potassium is used by plants in activating enzymes used in photosynthesis and respiration (Taiz and Zeiger 1998; Walker 1996). Stems of potassium deficient plants are often slender as compared to plants with a healthy supply of potassium (Taiz and Zeiger 1998), suggesting that American chestnut seedlings had an adequate supply of potassium because their stems were healthy and robust. Nitrate was also positively correlated to stem, root, and leaf parameters in 2002 and 2003. Many studies have demonstrated that when there is an increase in nitrogen there is an increase in stem mass, root mass, and specific leaf area (Freijsen 1990; Konings 1990; McDonald 1990; Chapin, et. al. 1998; Masarovicova et. al. 2000) because nitrogen frequently limits plant growth and is needed for the production of new foliage. In a study testing the effects of added nitrogen on pure American chestnuts and Chinese x American hybrids, Rieske et al. (2003) found that although both species showed a positive response to added nitrogen, the hybrid demonstrated a greater response than the pure American chestnut (Rieske et. al. 2003). These combined results may indicate that nitrogen could significantly impact the health of hybrid seedlings and should be carefully considered during reintroduction efforts.

Oddly, sand had a negative correlation to stem mass in chestnut seedlings in 2002, even though past research has shown that American chestnuts grow best in well-drained sandy soils (Russell 1987; Stephenson et. al. 1991). This may be due to a decrease in ability for sandy soil to retain moisture (Taiz and Zeiger 1998). Ashe (1911, 1922) found that chestnuts grew most robustly in lower coves with rich, deep, moist soils in Tennessee. This implies that chestnuts are adapted to a wide range of soil conditions. Since there was no correlation to sand in 2003, this indicates that sand and a potential water deficit may only impact seedlings during the initial recruitment stages.

In conclusion, stand level management had impacts on chestnut growth, suggesting that silvicultural practices could play a key role in chestnut's return to the eastern forests. In our study, American chestnut seedlings grew best in the thin+burn treatments. This suggests that with the aid of fire in forests that have already been thinned, hybrid chestnuts could have an increased rate of success at reclaiming their dominance in the overstory. Results also show that American chestnut seedlings prefer sunlight rather than shade (as in the thin and thin+burn treatments), even though they are capable of germinating and surviving under lower light conditions (as in the control and burn treatments). Therefore, it is recommended that American chestnut seeds be planted in areas with moderately high light conditions, with low surrounding competing vegetation for optimal growth benefits. However, adequate nutrients such as magnesium, nitrogen, and potassium have also been shown to affect chestnut growth and can significantly contribute to an American chestnut seedling’s health. Thus, site fertility should also be considered in reintroduction efforts.

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Table 1. ANOVA table of *Castanea dentata* biomass parameters. Forest is random and treatment is fixed in the GLM ANOVA.

Variable	Effect	df	MS	*F*	*P*
Number of leaves	Forest	2	0.15	7.85	< 0.001
	Treatment	3	1.53	24.95	< 0.001
Leaf mass	Forest	2	0.35	2.70	0.06
	Treatment	3	3.11	24.06	< 0.001
Leaf area	Forest	2	0.46	3.44	0.03
	Treatment	3	3.40	25.50	< 0.001
Specific leaf area	Forest	2	0.11	11.02	< 0.001
	Treatment	3	0.13	13.10	< 0.001
Basal diameter	Forest	2	0.22	16.84	< 0.001
	Treatment	3	0.35	26.89	< 0.001
Stem height	Forest	2	0.16	0.70	0.49
	Treatment	3	0.47	20.86	< 0.001
Stem mass	Forest	2	0.25	3.58	0.02
	Treatment	3	2.37	33.46	< 0.001
Root length	Forest	2	0.07	3.21	0.41
	Treatment	3	0.42	19.04	< 0.001
Root mass	Forest	2	0.42	5.06	0.006
	Treatment	3	2.49	30.30	< 0.001
Fine root mass	Forest	2	3.09	15.15	< 0.001
	Treatment	3	6.62	32.46	< 0.001
Total biomass	Forest	2	103.25	5.17	0.006
	Treatment	3	567.44	28.39	< 0.001

Table 2. Mean percentages of germination, survival and health rates of *Castanea dentata* seedlings (± SE) of each silvicultural treatment by year. Health rates: 1=healthy 4=defoliated

	2002			2003	
Treatment	Germination	Survival	Health	Survival	Health
Control (%)	71.33 ± 5.06	50.33 ± 5.08	2.46 ± 0.12	51.33 ± 5.42	2.37 ± 0.25
Burn (%)	70.33 ± 4.75	59.00 ± 4.96	2.38 ± 0.11	47.31 ± 6.38	2.14 ± 0.25
Thin (%)	62.00 ± 5.64	53.00 ± 5.73	1.79 ± 0.09	45.37 ± 6.05	2.23 ± 0.20
Thin + Burn (%)	64.33 ± 5.48	53.66 ± 5.53	2.27 ± 0.15	44.60 ± 6.48	1.89 ± 0.15

Table 3. Multiple regression relationships relating *Castanea dentata* biomass measurement results to environmental variables (*N* = 120). Only terms that have a statistically significant slope (*P* < 0.05) are included.

Dependent variable	Independent variable	Year significant	β	R^2	*P*
Basal diameter (cm)	Potassium ($mg \cdot g^{-1}$)	2002	0.723	0.415	0.045
	Light (%)	2003	2.834	0.306	<0.001
Stem height (cm)	Light (%)	2002	5.905	0.34	0.021
	Nitrate ($mg \cdot g^{-1}$)	2002	2.447	0.34	0.022
	Light (%)	2003	0.422	0.418	<0.001
Root length (g)	Light (%)	2002	10.627	0.478	<0.001
	Nitrate ($mg \cdot g^{-1}$)	2002	3.348	0.478	<0.001
	Light (%)	2003	0.389	0.454	<0.001
	Nitrate ($mg \cdot g^{-1}$)	2003	0.001	0.454	0.01
Stem mass (g)	Light (%)	2002	0.425	0.459	<0.001
	Nitrate ($mg \cdot g^{-1}$)	2002	0.123	0.459	0.024
	Sand (%)	2002	-0.733	0.459	0.042
	Light (%)	2003	0.773	0.429	<0.001
Root mass (g)	Light (%)	2002	0.622	0.452	<0.001
	Nitrate ($mg \cdot g^{-1}$)	2002	0.144	0.452	0.016
	Light (%)	2003	0.898	0.524	<0.001
	Magnesium ($mg \cdot g^{-1}$)	2003	0.215	0.524	0.016
	Nitrate($mg \cdot g^{-1}$)	2003	0.17	0.524	0.026
Fine root mass (g)	Light (%)	2002	0.747	0.36	<0.001
	Light (%)	2003	1.227	0.341	<0.001
Specific leaf area ($m^2\ g^{-1}$)	Magnesium ($mg \cdot g^{-1}$)	2002	0.219	0.33	0.042
	Nitrate ($mg \cdot g^{-1}$)	2002	0.22	0.33	0.016
	Sand (%)	2002	1.509	0.33	0.016
	Light (%)	2003	0.001	0.446	0.007
	Potassium ($mg \cdot g^{-1}$)	2003	0.004	0.446	0.006
Leaf mass (g)	Light (%)	2002	0.305	0.357	0.034
	Magnesium ($mg \cdot g^{-1}$)	2002	0.299	0.357	<.001
	Light (%)	2003	1.235	0.41	<0.001
	Magnesium ($mg \cdot g^{-1}$)	2003	0.297	0.41	0.032
leaf area (cm^2)	Light (%)	2002	0.562	0.378	<0.001
	Magnesium ($mg \cdot g^{-1}$)	2003	0.941	0.319	0.04
	Light (%)	2003	3.173	0.34	0.005
Leaves (number)	Light (%)	2003	2.152	0.34	0.003

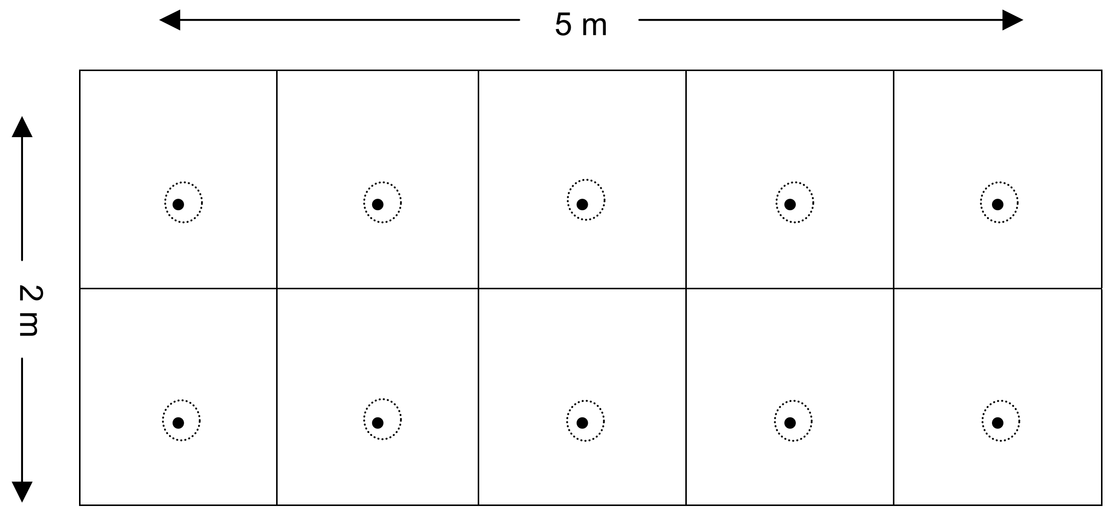

Figure 1. American chestnut plots in 1m^2 sections. Each • is an American chestnut seed. The dotted lines represent predator proof cages. American chestnut plots were 15 m from all Fire and Fire Surrogate study vegetation plots within the three study Forests of The Ohio Hills study region.

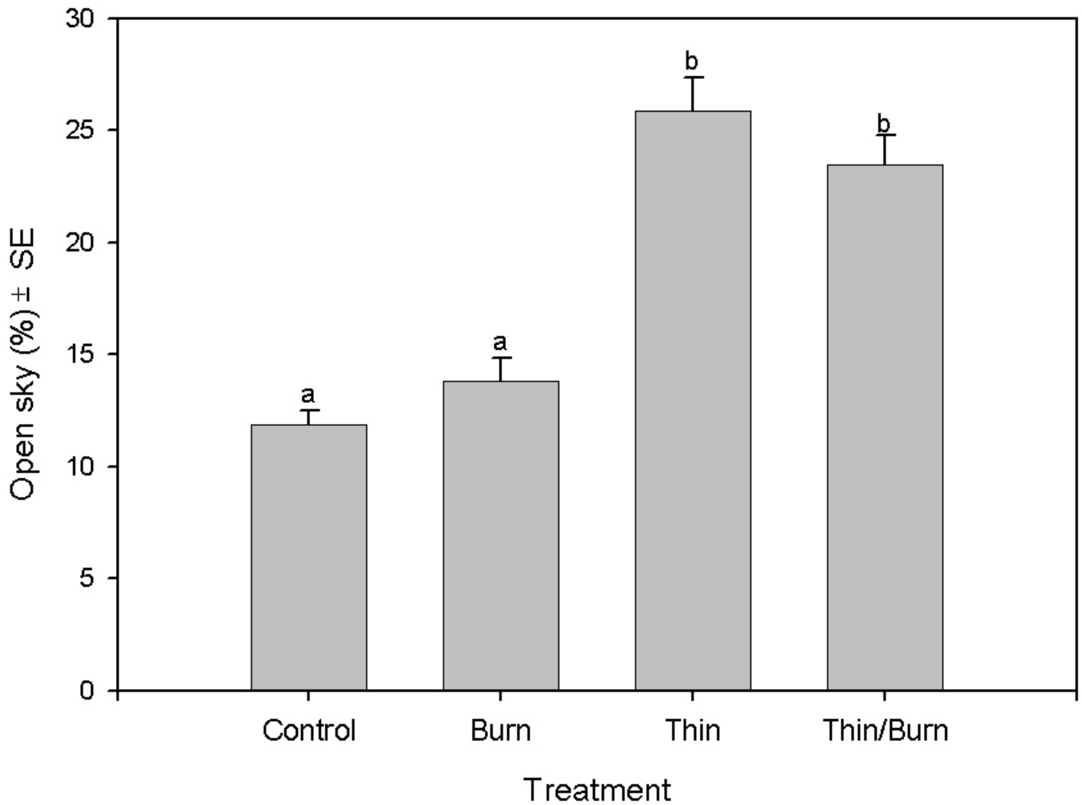

Figure 2. Percent open sky (± SE) by silvicultural treatment (ANOVA). Means with a different letter indicates a significant difference ($P < 0.05$).

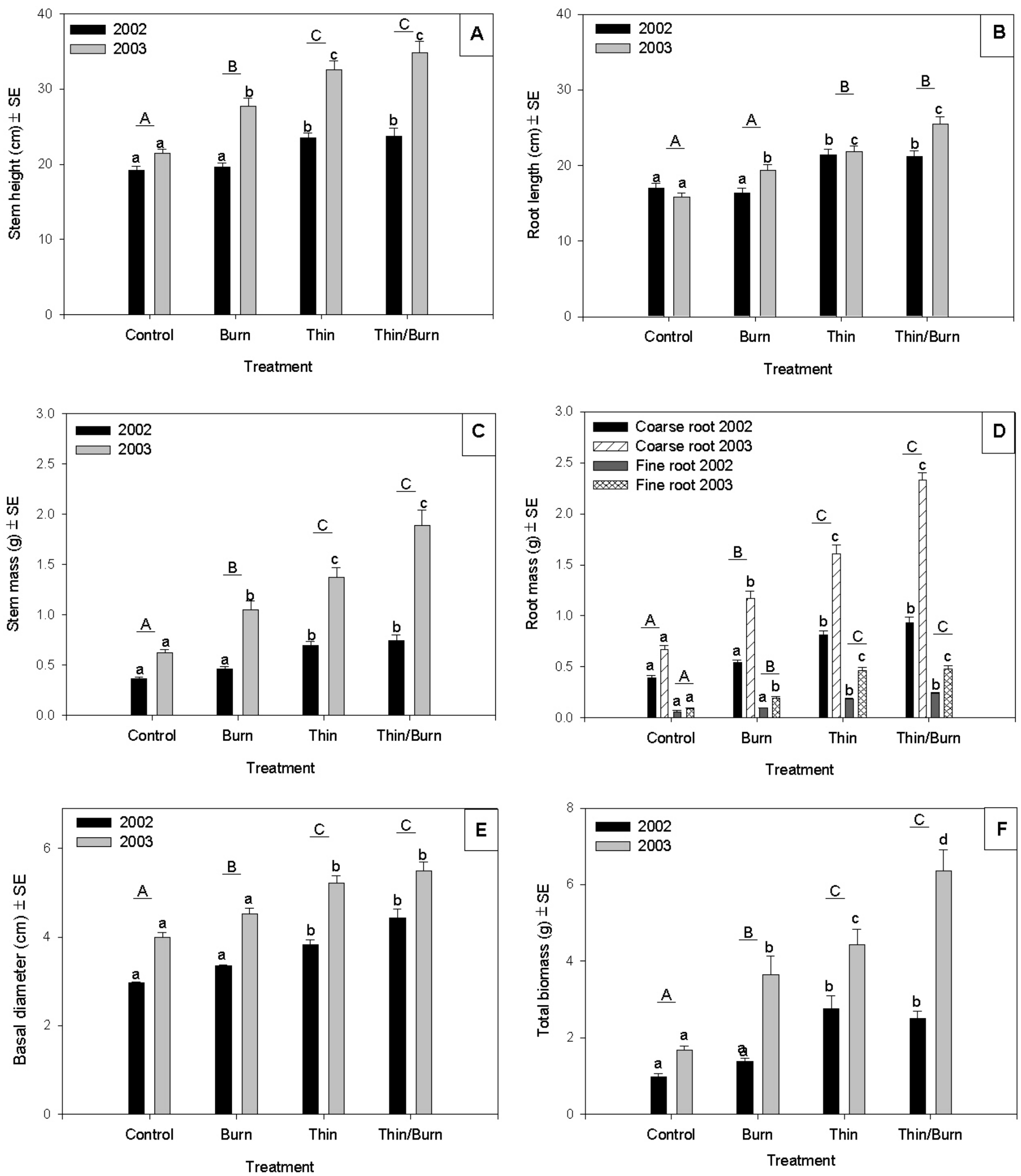

Figure 3. Growth measurements of *Castanea dentata* seedlings. Different lower case letters indicate significant differences among treatments within a year ($P < 0.05$). Different underlined capital letters indicate significant differences among treatment across years 2002 and 2003 ($P < 0.05$).

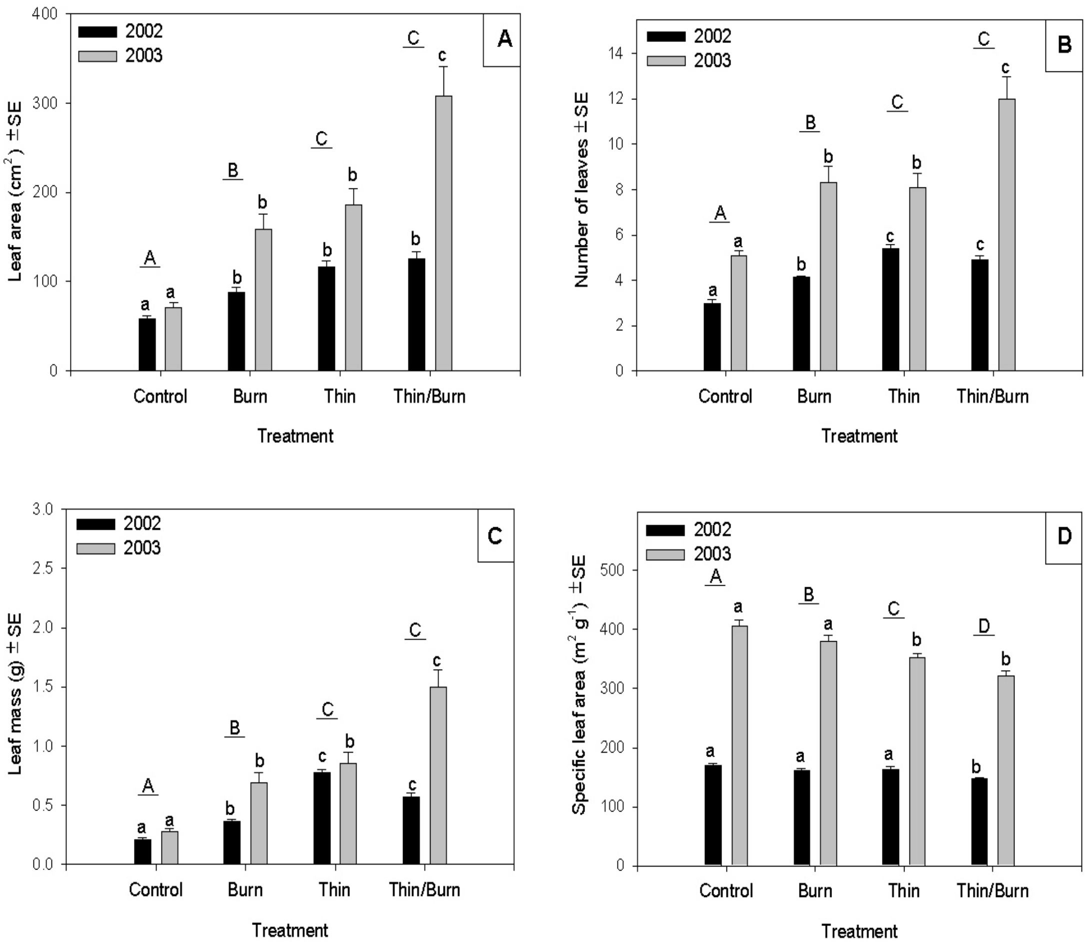

Figure 4. Leaf measurements of *Castanea dentata* seedlings. Different lower case letters indicate significant differences among treatments within a year (P < 0.05). Different underlined capital letters indicate significant differences among treatments across years 2002 and 2003 (P < 0.05).

Appendix 1. Environmental variable data of American chestnut plots. Cations are listed in Mg/g^{-1}. Soil texture, moisture, open sky and organic matter are listed as percentages. ND = No Data. Z=Zaleski, R=REMA,TH=Tar Hollow. C=Control, T=Thin, TB=Thin+burn, B=Burn.

Forest	Trmt	Plot	Open sky	PH	P	N	Ca	Mg	K	Sand	Silt	Clay	OM	SM
Z	C	1	10.74	5.30	2.20	53.34	-2.93	6.80	81.61	25.00	65.00	10.00	8.53	0.46
Z	C	2	15.30	4.71	0.06	42.00	-1.69	9.03	82.75	12.50	75.00	12.50	9.72	0.47
Z	C	3	12.05	4.56	2.10	44.93	9.12	10.94	74.09	50.00	42.50	7.50	8.78	0.44
Z	C	4	12.80	4.04	1.89	55.60	4.30	9.03	83.54	57.50	35.00	7.50	12.86	0.44
Z	C	5	15.43	4.40	2.10	50.47	213.3	17.82	78.51	27.50	60.00	12.50	9.75	0.47
Z	C	6	8.84	5.31	2.85	27.33	59.97	47.46	19.01	57.50	35.00	7.50	16.50	0.44
Z	C	7	12.32	4.45	1.28	43.42	2.33	8.26	74.69	47.50	40.00	12.50	9.11	0.47
Z	C	8	7.64	4.44	1.18	51.25	0.29	6.52	68.34	15.00	67.50	17.50	8.47	0.49
Z	C	9	12.66	5.03	2.10	28.43	0.97	32.53	64.08	62.50	27.50	10.00	8.92	0.46
Z	C	10	9.84	4.42	1.18	49.33	4.00	8.58	73.04	25.00	62.50	12.50	13.08	0.47
R	C	1	17.85	4.77	1.18	43.61	0.48	19.02	18.08	35.00	47.50	17.50	18.22	0.49
R	C	2	16.82	4.64	2.42	47.47	59.74	78.97	94.40	37.50	45.00	17.50	13.53	0.49
R	C	3	13.99	4.33	0.99	60.32	1.77	6.95	62.36	72.50	17.50	10.00	7.02	0.45
R	C	4	10.45	4.39	7.17	48.90	12.43	7.25	61.40	17.50	70.00	12.50	8.55	0.47
R	C	5	11.87	5.04	6.80	ND	5.06	11.71	89.37	52.50	37.50	10.00	57.95	0.46
R	C	6	19.67	4.58	6.42	ND	60.93	20.98	90.64	37.50	50.00	12.50	11.12	0.47
R	C	7	12.46	4.55	6.42	50.81	22.87	14.87	82.32	37.50	40.00	22.50	13.21	0.50
R	C	8	11.63	4.52	1.77	62.11	32.84	10.00	71.54	67.50	22.50	10.00	7.44	0.45
R	C	9	9.28	4.53	6.03	50.03	20.21	10.20	90.02	32.50	55.00	12.50	14.40	0.47
R	C	10	12.92	4.53	8.93	47.13	13.41	11.20	70.79	30.00	55.00	15.00	10.44	0.48
TH	C	1	11.35	4.40	5.22	38.01	0.45	15.39	89.00	30.00	57.50	12.50	22.81	0.47
TH	C	2	7.44	4.28	2.92	ND	0.60	8.31	59.82	70.00	22.50	7.50	7.69	0.44
TH	C	3	17.49	4.63	9.27	55.12	-0.49	11.75	84.37	30.00	57.50	12.50	13.03	0.47
TH	C	4	14.25	4.30	2.92	49.27	-2.62	6.93	69.43	27.50	60.00	12.50	13.27	0.47
TH	C	5	7.49	4.28	4.80	61.50	29.26	10.55	84.31	25.00	60.00	15.00	15.02	0.48
TH	C	6	7.78	4.52	1.77	52.87	13.32	17.73	76.93	25.00	62.50	12.50	10.52	0.47

TH	C	7	12.63	4.31	2.37	41.60	-3.60	7.92	67.54	12.50	70.00	17.50	8.58	0.49
TH	C	8	12.50	4.27	7.54	41.60	6.82	9.93	77.35	55.00	35.00	10.00	10.31	0.46
TH	C	9	5.78	4.35	5.63	57.07	2.74	7.03	68.46	32.50	57.50	10.00	8.31	0.46
TH	C	10	5.37	4.49	8.25	55.60	12.83	9.55	83.00	25.00	60.00	15.00	11.83	0.48
Z	T	1	14.96	4.37	12.69	59.86	-2.94	4.07	72.70	47.50	40.00	12.50	10.02	0.47
Z	T	2	37.08	4.13	5.63	64.01	17.74	11.88	96.40	20.00	67.50	12.50	12.06	0.47
Z	T	3	26.93	4.90	7.54	57.00	21.48	46.15	18.93	32.50	55.00	12.50	17.98	0.47
Z	T	4	23.98	4.48	5.22	53.03	-2.60	5.26	175.15	35.00	55.00	10.00	13.68	0.46
Z	T	5	21.45	4.60	8.25	63.03	8.02	8.98	85.37	10.00	75.00	15.00	10.64	0.48
Z	T	6	29.34	5.05	3.42	53.03	471.8	100.4	19.13	37.50	50.00	12.50	20.11	0.47
Z	T	7	30.00	4.35	1.08	59.86	22.94	8.04	85.09	35.00	50.00	15.00	11.93	0.48
Z	T	8	17.88	5.12	1.77	ND	43.14	122.6	41.56	35.00	50.00	15.00	15.58	0.48
Z	T	9	17.97	4.25	2.92	65.03	25.31	12.28	89.82	30.00	52.50	17.50	13.41	0.49
Z	T	10	17.12	4.81	6.80	47.56	14.74	25.86	12.65	25.00	57.50	17.50	14.63	0.49
R	T	1	39.28	3.76	3.42	157.00	10.00	7.11	72.78	60.00	32.50	7.50	10.60	0.44
R	T	2	20.42	4.16	2.91	ND	7.24	6.46	65.72	67.50	25.00	7.50	9.06	0.44
R	T	3	34.56	4.08	0.51	83.36	2.14	6.71	61.71	27.50	57.50	15.00	9.12	0.48
R	T	4	31.82	3.77	0.51	ND	2.50	6.61	60.17	47.50	45.00	7.50	9.71	0.44
R	T	5	38.03	3.85	0.86	ND	54.66	17.93	68.33	62.50	35.00	2.50	10.19	0.38
R	T	6	25.77	3.96	1.05	ND	9.40	14.76	143.41	42.50	47.50	10.00	18.74	0.46
R	T	7	18.09	3.87	0.95	66.08	14.15	23.34	82.68	57.50	32.50	10.00	14.01	0.46
R	T	8	25.37	4.08	0.86	109.43	6.69	13.45	94.18	45.00	45.00	10.00	12.79	0.46
R	T	9	20.11	4.03	0.51	36.33	8.63	14.44	93.60	70.00	22.50	7.50	11.16	0.44
R	T	10	21.87	3.64	1.22	86.52	0.89	6.73	53.69	60.00	30.00	10.00	10.44	0.46
TH	T	1	16.71	3.76	2.10	ND	21.09	6.50	72.65	40.00	45.00	15.00	11.67	0.48
TH	T	2	15.76	3.44	1.11	57.00	0.73	2.17	52.66	47.50	40.00	12.50	10.87	0.47
TH	T	3	20.46	3.90	1.88	ND	16.22	5.46	59.36	47.50	45.00	7.50	7.56	0.44
TH	T	4	24.61	3.88	1.22	ND	3.75	4.17	62.69	35.00	55.00	10.00	8.00	0.46
TH	T	5	30.12	3.50	0.50	100.77	16.24	4.27	49.64	37.50	52.50	10.00	10.19	0.46
TH	T	6	29.75	3.60	2.56	ND	1.10	0.92	60.17	35.00	50.00	15.00	10.32	0.48

TH	T	7	48.06	3.62	0.70	ND	0.82	1.28	55.45	62.50	30.00	7.50	8.58	0.44
TH	T	8	34.22	3.39	2.68	90.09	0.83	1.04	58.44	45.00	47.50	7.50	8.90	0.44
TH	T	9	23.40	3.87	0.80	37.27	5.87	6.77	75.06	60.00	35.00	5.00	8.56	0.42
TH	T	10	21.88	4.41	1.54	ND	101.7	261.80	95.65	57.50	32.50	10.00	20.36	0.46
Z	TB	1	34.56	4.19	1.22	ND	7.34	6.12	152.30	42.50	50.00	7.50	9.87	0.44
Z	TB	2	30.12	3.73	1.32	46.74	2.86	1.50	62.77	70.00	25.00	5.00	10.62	0.42
Z	TB	3	29.64	3.75	1.32	ND	6.10	2.80	63.51	55.00	35.00	10.00	6.80	0.46
Z	TB	4	29.95	4.12	1.22	52.70	249.2	50.82	96.97	42.50	45.00	12.50	20.43	0.47
Z	TB	5	21.29	4.33	1.88	ND	15.25	6.20	74.92	57.50	32.50	10.00	8.57	0.46
Z	TB	6	38.68	4.96	1.54	69.50	79.34	62.94	92.99	72.50	22.50	5.00	9.40	0.42
Z	TB	7	22.93	4.15	1.22	ND	63.93	47.80	202.23	37.50	47.50	15.00	16.28	0.48
Z	TB	8	19.66	5.12	0.60	58.60	387.7	118.40	99.49	55.00	40.00	5.00	13.07	0.42
Z	TB	9	20.99	4.94	1.22	ND	ND	199.70	89.27	55.00	32.50	12.50	14.58	0.47
Z	TB	10	24.11	4.33	7.75	63.03	10.33	8.40	59.69	65.00	27.50	7.50	9.16	0.44
R	TB	1	23.53	3.70	0.70	60.73	22.94	3.12	64.77	55.00	37.50	7.50	5.72	0.44
R	TB	2	25.20	3.83	0.70	80.52	1.27	1.74	55.38	70.00	22.50	7.50	4.74	0.44
R	TB	3	18.65	3.89	1.22	72.71	0.50	1.60	57.47	57.50	32.50	10.00	6.33	0.46
R	TB	4	21.09	3.99	1.28	63.52	14.67	3.83	68.43	70.00	25.00	5.00	7.75	0.42
R	TB	5	28.02	4.25	1.15	66.62	697.1	11.99	76.94	20.00	50.00	30.00	11.78	0.52
R	TB	6	23.91	5.02	1.42	ND	15.17	10.14	14.32	22.50	52.50	25.00	14.31	0.51
R	TB	7	18.53	4.33	1.69	87.66	24.49	9.57	76.00	60.00	27.50	12.50	12.38	0.47
R	TB	8	17.01	5.29	1.83	90.09	1.31	2.71	84.58	62.50	25.00	12.50	9.27	0.47
R	TB	9	15.02	4.79	1.96	70.74	3.78	1.29	60.68	65.00	22.50	12.50	3.97	0.47
R	TB	10	30.65	4.27	1.69	74.83	12.85	4.39	86.90	50.00	35.00	15.00	8.57	0.48
TH	TB	1	39.03	4.05	0.75	ND	1.57	8.08	78.91	17.50	67.50	15.00	7.86	0.48
TH	TB	2	22.49	3.50	0.62	50.66	1.04	6.33	73.03	45.00	47.50	7.50	11.27	0.44
TH	TB	3	20.26	3.42	0.88	48.64	0.05	6.28	70.47	42.50	50.00	7.50	0.25	0.44
TH	TB	4	30.19	3.83	0.49	49.63	354.0	16.28	70.79	25.00	62.50	12.50	10.74	0.47
TH	TB	5	24.12	3.89	1.69	36.57	13.84	6.48	92.81	32.50	57.50	10.00	10.29	0.46
TH	TB	6	17.11	4.05	1.01	36.57	1.31	6.13	65.67	27.50	62.50	10.00	10.54	0.46

TH	TB	7	20.58	4.05	0.88	54.34	0.91	6.57	73.81	50.00	40.00	10.00	8.12	0.46
TH	TB	8	10.93	4.28	1.55	ND	279.5	120.40	210.13	30.00	55.00	15.00	19.65	0.48
TH	TB	9	8.50	3.87	1.28	44.66	57.49	9.44	70.53	50.00	42.50	7.50	11.95	0.44
TH	TB	10	17.33	4.02	1.69	53.57	19.91	18.34	81.46	35.00	55.00	10.00	9.51	0.46
Z	B	1	31.50	4.01	1.69	ND	5.25	15.67	68.44	42.50	50.00	7.50	9.06	0.44
Z	B	2	18.10	3.78	1.42	19.37	18.86	12.47	57.70	50.00	42.50	7.50	7.69	0.44
Z	B	3	18.90	4.22	1.69	29.07	46.23	37.37	63.21	22.50	65.00	12.50	14.94	0.47
Z	B	4	21.98	4.26	1.01	50.58	3.73	11.87	61.04	15.00	65.00	20.00	14.38	0.50
Z	B	5	13.55	3.71	1.28	47.95	534.6	11.21	54.75	32.50	52.50	15.00	11.75	0.48
Z	B	6	18.64	3.86	0.75	52.73	444.8	16.69	65.18	20.00	60.00	20.00	11.06	0.50
Z	B	7	15.69	3.82	1.28	56.29	869.7	7.73	44.68	25.00	62.50	12.50	9.25	0.47
Z	B	8	15.88	3.99	1.62	ND	5.91	26.92	59.37	37.50	55.00	7.50	11.56	0.44
Z	B	9	14.75	4.37	3.34	37.74	15.38	8.41	80.50	42.50	50.00	7.50	19.27	0.44
Z	B	10	14.96	3.82	0.92	24.15	2.84	910.30	74.94	37.50	55.00	7.50	6.83	0.44
R	B	1	11.25	3.43	1.62	ND	9.70	8.06	73.78	22.50	67.50	10.00	15.54	0.46
R	B	2	23.52	3.45	1.34	52.73	46.95	8.70	74.88	22.50	65.00	12.50	89.03	0.47
R	B	3	16.78	3.99	1.76	49.24	83.40	29.81	76.66	15.00	70.00	15.00	11.01	0.48
R	B	4	21.39	4.34	0.92	ND	54.94	18.55	69.79	25.00	65.00	10.00	13.11	0.46
R	B	5	11.56	4.50	2.62	13.33	24.67	59.69	83.81	22.50	62.50	15.00	10.70	0.48
R	B	6	10.56	4.50	1.34	12.41	308.2	19.34	73.23	17.50	72.50	10.00	9.82	0.46
R	B	7	7.69	5.19	1.34	28.27	54.94	228.00	87.36	32.50	62.50	5.00	12.84	0.42
R	B	8	10.04	4.24	1.76	58.48	24.67	9.77	74.72	25.00	60.00	15.00	20.37	0.48
R	B	9	10.69	4.49	1.20	53.11	308.2	53.28	76.86	15.00	77.50	7.50	8.76	0.44
R	B	10	8.89	4.20	0.65	53.87	34.50	20.04	68.33	27.50	65.00	7.50	13.02	0.44
TH	B	1	11.11	4.98	1.76	ND	5.23	7.44	76.62	10.00	77.50	12.50	10.55	0.47
TH	B	2	7.00	4.79	1.62	31.44	26.13	10.00	75.51	12.50	77.50	10.00	9.64	0.46
TH	B	3	12.09	3.99	0.51	37.71	81.19	4.16	71.20	12.50	75.00	12.50	6.70	0.47
TH	B	4	14.72	4.03	1.48	45.53	22.32	5.87	69.20	12.50	75.00	12.50	6.93	0.47
TH	B	5	14.16	3.60	2.33	48.31	105.6	11.72	76.82	25.00	67.50	7.50	14.83	0.44
TH	B	6	10.65	3.59	0.78	43.80	41.75	12.14	81.40	42.50	50.00	7.50	11.85	0.44

TH	B	7	5.00	3.72	1.62	13.43	140.7	31.10	86.21	37.50	55.00	7.50	10.86	0.44
TH	B	8	6.28	4.31	1.20	33.80	78.28	32.48	90.48	27.50	65.00	7.50	8.65	0.44
TH	B	9	8.21	4.62	1.76	15.42	222.7	51.53	86.68	22.50	65.00	12.50	8.65	0.47
TH	B	10	9.21	3.65	1.20	46.13	11.91	6.62	97.96	32.50	60.00	7.50	8.89	0.44

Appendix 2. 2002 American chestnut biomass data. Values means (top number) ± SE (bottom number). Values without an SE there was only one seedling in plot. NS = No Standard Error. Mass (g), area (cm^2), height and length (m). ND = No Data.

Forest	Trmt	Plot	Total biomass	# of lvs	Lf. mass	Lf. area	Basal d	Stem height	Stem mass	Root length	Root mass	Fine root mass	Root: Shoot
			0.22	4.50	0.22	79.96	ND	ND	ND	ND	ND	ND	ND
Z	C	1	NS	1.50	0.22	59.14	NS	NS	NS	NS	NS	NS	NS
			1.66	1.66	0.15	27.58	3.20	20.00	1.03	24.00	0.46	0.01	0.46
Z	C	2	NS	0.33	0.27	7.71	0.05	2.30	0.07	2.40	0.32	0.01	0.43
			1.09	2.42	0.11	30.78	3.10	19.00	0.68	15.00	0.24	0.04	0.41
Z	C	3	0.18	0.88	0.05	10.96	0.02	1.0	0.06	5.03	0.06	0.01	0.08
			1.34	2.60	0.20	61.63	3.60	21.00	0.82	16.50	0.23	0.09	0.40
Z	C	4	NS	0.81	0.11	27.2	NS	NS	NS	NS	NS	NS	NS
			1.48	2.00	0.10	21.82	3.30	21.00	0.97	21.50	0.36	0.07	0.47
Z	C	5	0.14	0.5	0.05	9.75	0.10	3.0	0.02	1.50	0.008	0.05	0.04
			1.15	2.80	0.17	56.88	2.62	19.62	0.70	12.00	0.22	0.04	0.39
Z	C	6	0.12	0.66	0.05	18.48	0.22	3.17	0.07	2.52	0.03	0.01	0.10
			1.02	2.71	0.15	32.33	2.63	14.33	0.50	16.00	0.28	0.07	0.72
Z	C	7	0.04	0.02	0.02	3.71	0.23	1.76	0.04	0.50	0.04	0.02	0.27
			2.70	2.20	0.24	53.72	4.20	22.00	1.47	14.50	0.77	0.20	0.66
Z	C	8	0.43	0.17	0.17	52.55	0.30	2.0	0.19	0.30	0.01	0.03	0.26
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z	C	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			1.40	2.57	0.13	37.20	2.90	15.25	0.73	17.75	0.42	0.10	0.72
Z	C	10	0.27	0.86	0.31	9.48	0.49	2.17	0.10	1.31	0.10	0.07	0.24
			1.56	2.20	0.19	53.94	3.23	23.16	1.00	14.83	0.31	0.04	0.36
R	C	1	0.17	0.66	0.05	15.28	0.14	1.01	0.07	2.20	0.65	0.01	0.05
			1.97	3.37	0.30	76.82	3.16	18.16	0.85	20.83	0.69	0.11	0.94
R	C	2	0.57	0.57	0.15	36.94	0.78	2.68	0.09	5.67	0.26	0.06	0.25
			0.13	1.66	0.13	34.10	ND	ND	ND	ND	ND	ND	ND
R	C	3	Ns	0.33	0.07	15.23	NS	NS	NS	NS	NS	NS	NS
			0.09	1.50	0.09	28.40	ND	ND	ND	ND	ND	ND	ND
R	C	4	NS	0.50	0.05	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	C	5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			1.38	2.80	0.17	69.31	2.83	18.33	0.76	12.50	0.41	0.02	0.57
R	C	6	0.47	0.20	0.01	69.41	0.67	4.37	0.19	1.80	0.28	0.01	0.25
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	C	7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

			1.33	1.50	0.08	25.88	3.13	21.33	0.84	19.66	0.33	0.07	0.48
R	C	8	0.13	0.22	0.02	10.15	0.08	0.44	0.19	2.33	0.50	0.01	0.01
			0.23	4.33	0.23	72.05	ND	ND	ND	ND	ND	ND	ND
R	C	9	NS	0.66	0.11	31.29	NS	NS	NS	NS	NS	NS	NS
			0.15	3.00	0.15	23.70	ND	ND	ND	ND	ND	ND	ND
R	C	10	NS	1.00	0.008	3.30	NS	NS	NS	NS	NS	NS	NS
			1.51	4.33	0.34	96.95	2.80	20.00	0.79	17.00	0.34	0.04	0.48
TH	C	1	NS	0.66	0.68	21.01	NS	NS	NS	NS	NS	NS	NS
			1.13	3.40	0.27	73.94	2.63	14.33	0.53	14.30	0.27	0.05	0.62
TH	C	2	0.10	1.00	0.24	72.1	0.02	0.88	0.01	5.04	0.84	0.04	0.27
			1.84	2.33	0.28	74.82	3.30	19.00	0.94	29.00	0.55	0.07	0.66
TH	C	3	NS	0.66	0.08	23.30	NS	NS	NS	NS	NS	NS	NS
			1.27	3.50	0.13	40.02	2.95	20.66	0.81	17.50	0.28	0.04	0.40
TH	C	4	0.13	2.00	0.04	14.41	0.30	1.37	0.01	2.94	0.68	0.08	0.16
			1.61	2.66	0.38	78.41	3.10	20.00	0.76	15.12	0.44	0.02	0.60
TH	C	5	0.43	0.5	0.25	5.79	0.15	4.91	0.48	1.80	0.10	0.01	0.18
			2.31	5.00	0.39	122.73	3.15	21.75	1.17	20.25	0.63	0.10	0.63
TH	C	6	0.41	1.03	0.16	48.24	0.29	2.05	0.13	3.35	0.17	0.09	0.25
			1.48	4.44	0.21	58.58	2.84	18.7	0.81	17.50	0.43	0.02	0.56
TH	C	7	0.23	0.25	0.08	19.05	0.21	1.25	0.06	2.60	0.12	0.01	0.21
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	C	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			1.04	3.66	0.16	48.78	2.43	15.00	0.55	18.3	0.30	0.01	0.57
TH	C	9	0.14	4.52	0.05	17.52	0.18	1.52	0.01	3.38	0.74	0.005	0.28
			1.22	2.75	0.15	45.32	2.66	23.33	0.76	15.60	0.27	0.02	0.39
TH	C	10	0.06	0.47	0.05	NS	NS	3.84	0.04	1.76	0.60	0.04	0.32
			2.39	5.33	0.34	88.24	3.40	21.00	1.06	23.30	0.94	0.03	0.92
Z	T	1	0.41	1.20	0.10	23.58	0.05	2.30	0.07	2.40	0.32	0.01	0.45
			4.16	1.00	0.13	21.87	ND	25.00	1.71	30.00	1.70	0.61	1.34
Z	T	2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.05
			3.43	6.11	0.83	135.06	4.65	23.66	1.32	20.60	0.99	0.27	0.96
Z	T	3	0.59	0.75	0.16	44.29	0.17	0.81	0.11	2.79	0.49	0.15	0.13
			2.04	3.14	0.37	71.83	4.13	24.66	1.04	18.60	0.49	0.12	0.59
Z	T	4	0.54	1.00	0.57	30.58	0.32	3.75	0.14	2.33	0.19	0.06	0.13
			2.30	1.66	0.20	21.40	3.26	22.75	1.32	16.75	0.71	0.06	0.58
Z	T	5	0.41	0.30	0.07	12.84	0.58	6.64	0.19	1.76	0.12	0.03	0.33
			0.24	3.28	0.24	53.56	3.22	ND	ND	ND	ND	ND	ND
Z	T	6	0.58	1.18	0.09	23.34	2.86	NS	NS	NS	NS	NS	NS
Z	T	7	0.31	3.75	0.31	52.49	ND	ND	ND	ND	ND	ND	ND

			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			2.21	4.22	0.32	66.71	3.47	21.50	1.02	19.75	0.72	0.14	0.84
Z	T	8	0.29	0.70	0.16	14.93	0.86	0.86	0.93	2.09	0.10	0.02	0.10
			2.38	7.20	0.62	153.00	2.85	18.50	0.67	23.50	0.77	0.31	1.61
Z	T	9	0.76	0.50	0.24	64.06	5.50	5.50	0.21	0.50	0.02	0.03	0.13
			1.61	3.50	0.20	52.61	3.06	17.66	0.79	19.66	0.56	0.06	0.79
Z	T	10	0.16	1.00	0.06	22.90	0.33	0.33	0.25	0.33	0.08	0.02	1.99
			1.02	8.00	1.02	208.02	ND	ND	ND	ND	ND	ND	ND
R	T	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			4.09	10.25	0.82	176.1	5.06	28.83	1.87	22.6	0.88	0.50	0.74
R	T	2	1.14	8.50	0.06	149.63	0.29	1.76	0.13	2.90	0.31	0.21	0.21
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			3.16	6.00	0.66	140.14	4.50	18.00	1.34	18.3	0.89	0.25	0.85
R	T	8	0.46	0.50	0.12	32.72	0.45	0.28	0.21	1.64	0.14	0.10	0.33
			3.20	4.83	0.50	127.96	4.86	19.50	1.34	21.83	0.82	0.53	1.01
R	T	9	0.52	0.66	0.23	30.05	0.39	2.36	NS	5.00	0.18	0.19	0.15
			0.46	3.50	0.46	115.46	ND	ND	ND	ND	ND	ND	ND
R	T	10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			4.32	7.77	0.97	212.86	4.32	30.30	1.84	29.75	1.35	0.15	0.81
TH	T	1	0.82	0.83	0.34	58.10	0.23	2.84	0.15	4.83	0.26	0.04	0.19
			2.31	5.00	0.48	113.45	3.26	23.43	1.08	18.5	0.71	0.02	0.68
TH	T	2	0.36	1.15	0.18	37.73	0.20	0.69	0.04	3.50	0.13	0.01	0.17
			1.72	4.00	0.24	88.32	3.60	23.50	0.95	17.00	0.50	0.03	0.56
TH	T	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			0.40	3.00	0.40	17.12	ND	ND	ND	ND	ND	ND	ND
TH	T	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			2.04	5.11	0.46	129.07	3.55	23.45	1.12	19.75	0.39	0.06	0.40
TH	T	5	0.35	1.03	0.09	28.60	0.49	0.94	0.11	±1.10	0.12	0.03	0.09
			3.13	6.66	0.74	165.06	3.55	26.62	1.63	21.87	0.66	0.09	0.46
TH	T	6	0.86	0.40	0.80	10.68	0.32	2.03	0.10	2.45	0.15	0.04	0.10

			4.34	8.37	1.03	199.04	4.60	26.37	2.18	19.75	0.93	0.19	0.51
TH	T	7	0.40	0.94	0.12	17.26	0.40	2.26	0.15	2.45	0.12	0.05	0.05
			3.10	7.12	0.74	126.98	3.85	25.37	1.55	25.25	0.73	0.06	0.51
TH	T	8	0.56	2.39	0.21	39.73	0.27	2.67	0.12	4.00	0.23	0.01	0.17
			1.99	5.66	0.38	102.84	3.40	20.00	1.18	20.25	0.31	0.10	0.35
TH	T	9	0.18	1.00	0.06	22.17	0.10	2.00	0.06	6.25	0.03	0.01	0.01
			2.19	5.55	0.45	115.46	3.30	23.00	1.19	15.37	0.50	0.04	0.46
TH	T	10	0.60	1.45	0.14	39.76	0.69	1.15	0.27	2.44	0.19	0.04	0.08
			2.44	2.40	0.21	39.00	5.00	23.25	1.23	21.00	0.77	0.21	0.80
Z	TB	1	0.19	1.00	0.07	16.04	0.50	5.25	0.18	1.50	0.08	0.17	0.48
			5.58	6.44	0.89	159.70	7.14	23.75	2.32	28.87	1.57	0.78	1.01
Z	TB	2	0.65	0.85	0.10	17.01	0.69	2.27	0.21	1.97	0.17	0.29	0.19
			3.83	3.80	0.48	83.36	6.35	24.75	1.81	17.50	1.35	0.18	0.84
Z	TB	3	0.92	1.00	0.31	57.06	1.15	1.75	0.19	2.00	0.35	0.06	0.09
			1.31	5.80	0.82	178.24	1.90	11.50	0.21	19.50	0.27	0.01	1.35
Z	TB	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			2.04	2.00	0.20	39.19	3.63	23.33	1.08	20.00	0.67	0.07	0.69
Z	TB	5	0.41	0.04	0.04	8.32	0.23	4.08	0.10	2.78	0.27	0.28	0.24
			4.68	2.87	0.48	80.51	6.27	32.00	2.50	23.00	1.18	0.49	0.67
Z	TB	6	0.31	0.04	0.04	6.96	0.74	1.27	0.15	3.67	0.24	0.12	0.17
			5.20	5.28	0.88	157.12	3.45	27.16	1.88	26.83	2.17	0.25	1.29
Z	TB	7	0.43	0.20	0.20	37.58	0.86	3.03	0.12	0.60	0.25	0.32	0.34
			3.86	6.17	0.67	126.59	5.40	22.00	1.57	28.00	1.30	0.32	1.03
Z	TB	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			0.30	3.00	0.30	45.62	ND	ND	ND	ND	ND	ND	ND
Z	TB	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			4.80	5.50	0.67	171.31	5.50	26.83	2.29	17.83	1.36	0.47	0.80
Z	TB	10	1.21	1.20	0.04	124.45	0.10	4.96	0.48	1.30	0.37	0.15	0.26
			ND	5.00	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	TB	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			2.97	6.57	0.80	169.88	3.57	26.75	1.32	22.12	0.65	0.19	0.64
R	TB	2	0.69	1.55	0.20	44.17	0.49	6.50	0.22	2.67	0.18	0.12	0.16
			4.04	5.00	0.78	149.35	4.50	20.25	1.64	31.50	1.32	0.29	0.98
R	TB	3	0.38	0.50	0.16	28.16	0.50	3.75	0.16	4.50	0.01	0.07	0.34
			0.09	3.00	0.09	25.18	ND	ND	ND	ND	ND	ND	ND
R	TB	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	TB	5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		6	3.82	5.00	0.55	143.09	5.20	27.00	2.17	22.66	0.82	0.26	0.50

R	TB		0.68	1.52	0.23	64.04	0.70	4.33	0.14	3.37	0.29	0.12	0.41
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	TB	7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			0.15	5.00	0.15	48.07	ND	ND	ND	ND	ND	ND	ND
R	TB	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	4.00	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	TB	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			1.93	3.60	0.52	110.62	2.75	15.75	0.45	8.50	0.89	0.05	2.09
R	TB	10	0.10	1.00	0.04	15.17	0.25	2.25	0.02	3.50	0.12	0.04	0.61
			3.35	5.57	0.73	168.58	3.82	20.55	1.46	23.37	1.08	0.06	0.78
TH	TB	1	0.65	0.50	0.03	18.32	0.45	2.25	0.10	2.50	0.06	0.02	0.04
			2.06	6.00	0.73	152.65	2.70	18.8	0.73	15.00	0.30	0.27	0.79
TH	TB	2	0.65	1.22	0.33	62.98	0.38	2.38	0.16	2.40	0.21	0.14	0.13
			1.28	13.00	1.28	276.60	ND	ND	ND	ND	ND	ND	ND
TH	TB	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	TB	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			0.89	3.60	0.10	55.58	2.40	16.65	0.51	16.00	0.25	0.02	0.53
TH	TB	5	0.008	0.01	0.004	9.78	0.10	3.15	0.05	3.00	0.04	0.004	0.61
			2.26	7.50	0.74	201.14	3.15	25.75	0.93	15.50	0.48	0.09	0.61
TH	TB	6	0.63	0.75	0.19	34.89	0.65	0.18	0.18	2.15	0.03	0.13	0.08
			2.42	3.00	0.24	58.27	3.87	19.00	1.34	21.75	0.83	0.01	0.63
TH	TB	7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			3.57	5.75	0.71	183.03	4.00	28.12	1.86	18.75	0.85	0.13	0.53
TH	TB	8	0.60	1.08	0.27	56.11	0.37	0.13	0.13	1.88	0.05	0.05	0.18
			1.89	5.25	0.28	79.04	3.40	22.75	1.17	15.00	0.30	0.12	0.36
TH	TB	9	0.29	1.50	0.08	25.38	0.70	0.15	0.15	3.0	0.04	0.04	0.20
			2.34	4.00	0.37	111.78	3.20	21.96	1.22	23.90	0.68	0.05	0.60
TH	TB	10	0.64	1.76	0.33	100.73	0.45	0.20	0.20	2.87	0.02	0.02	0.33
			3.43	9.00	0.68	134.98	4.16	21.66	1.66	23.30	0.95	0.13	0.65
Z	B	1	0.35	0.33	0.21	35.34	0.32	1.45	0.02	4.17	0.17	0.05	0.18
			2.30	7.57	0.33	76.58	3.80	18.66	1.02	19.00	0.72	0.21	0.92
Z	B	2	0.64	1.20	0.19	41.03	0.60	3.21	0.01	1.15	0.95	0.02	0.28
			1.33	3.80	0.21	65.11	3.20	18.66	0.73	15.60	0.36	0.02	0.51
Z	B	3	0.24	0.01	0.02	6.77	0.15	0.33	0.05	3.48	0.11	0.01	0.20
			2.50	3.7	0.45	89.48	3.86	22.66	1.10	18.30	0.81	0.12	0.85
Z	B	4	0.33	1.45	0.03	18.84	0.06	1.33	0.07	3.28	0.27	0.03	0.42
			0.82	5.00	0.18	41.56	2.20	11.00	0.27	12.00	0.34	0.03	1.37
Z	B	5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

			1.85	3.33	0.28	74.00	3.80	22.00	1.00	23.00	0.51	0.04	0.55
Z	B	6	0.02	0.01	0.01	0.07	0.20	2.00	0.04	2.00	0.02	0.009	0.14
			3.11	5.00	0.57	147.88	4.00	27.25	1.70	18.50	0.70	0.12	0.48
Z	B	7	0.27	2.02	0.17	48.05	0.10	4.20	0.09	2.84	0.12	0.05	0.17
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z	B	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			0.37	5.00	0.37	89.61	ND	ND	ND	ND	ND	ND	ND
Z	B	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			1.62	4.22	0.33	98.53	3.16	18.33	0.74	17.60	0.47	0.06	0.72
Z	B	10	0.08	0.04	0.04	12.67	0.57	1.20	0.06	4.90	0.77	0.01	0.21
			1.06	3.00	0.12	35.89	2.85	18.00	0.72	10.00	0.18	0.04	0.31
R	B	1	0.18	1.00	0.07	5.34	NS	NS	0.14	1.00	0.77	0.01	0.21
			4.18	3.00	0.79	175.27	4.83	25.83	1.94	24.00	1.17	0.26	0.74
R	B	2	0.17	0.33	0.02	2.51	0.35	3.40	0.12	1.00	0.02	0.07	0.14
			2.87	7.14	0.53	126.46	4.35	19.75	1.18	16.50	0.90	0.26	0.98
R	B	3	0.60	0.23	0.12	37.07	0.47	1.88	0.14	2.90	0.06	0.02	0.13
			1.58	6.11	0.21	53.67	2.96	17.16	0.82	14.16	0.45	0.08	0.65
R	B	4	0.25	1.73	0.07	16.90	0.30	3.32	0.13	1.42	0.22	0.04	0.63
			2.14	3.60	0.42	88.53	3.43	18.66	0.96	14.00	0.55	0.19	0.77
R	B	5	0.17	0.88	0.11	24.11	0.03	0.88	0.57	1.73	0.11	0.10	0.22
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	B	6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	B	7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			1.34	3.62	0.16	45.64	3.13	17.66	0.76	12.00	0.37	0.03	0.53
R	B	8	0.33	0.66	0.06	16.00	0.35	1.76	0.12	2.08	0.14	0.01	0.15
			2.10	2.42	0.20	51.64	3.76	22.83	1.23	17.00	0.61	0.05	0.53
R	B	9	0.06	0.33	0.06	21.85	0.31	1.09	0.63	1.52	0.47	0.01	0.04
			2.10	4.00	0.26	64.66	5.30	24.50	1.08	19.50	0.73	0.04	0.71
R	B	10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			1.00	ND	0.15	ND	ND	20.00	0.30	20.00	0.51	0.03	1.80
TH	B	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			0.98	2.60	0.19	51.1	2.56	20.00	0.52	10.50	0.21	0.04	0.49
TH	B	2	0.27	2.00	0.17	50.98	0.29	3.05	0.07	2.75	0.72	0.01	0.02
			1.27	5.00	0.29	71.07	2.40	13.66	0.56	14.60	0.39	0.03	0.74
TH	B	3	0.20	NS	NS	NS	0.41	2.02	0.09	3.17	0.10	0.01	0.03
			2.24	3.60	0.46	104.79	3.56	18.33	1.14	12.50	0.46	0.17	0.55
TH	B	4	0.33	NS	NS	NS	0.47	1.45	0.11	0.86	0.14	0.07	0.30
		5	1.86	4.42	0.43	103.80	3.03	18.33	0.83	18.16	0.54	0.05	0.71

TH	B		0.46	1.45	0.22	3.88	0.24	1.20	0.08	3.24	0.20	0.03	0.18
			1.61	5.00	0.35	81.17	2.92	17.62	0.72	17.75	0.49	0.03	0.74
TH	B	6	0.19	0.57	0.52	10.14	0.30	1.43	0.07	2.04	0.10	0.02	0.29
			1.45	4.87	0.26	77.27	2.90	16.37	0.74	16.25	0.42	0.02	0.60
TH	B	7	0.23	0.62	0.08	22.44	0.25	3.14	0.05	3.54	0.10	0.04	0.25
			0.91	4.67	0.26	77.90	ND	13.00	0.31	14.50	0.26	0.08	1.11
TH	B	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			0.75	2.00	0.06	46.21	2.20	19.66	0.46	8.83	0.15	0.07	0.49
TH	B	9	NS	NS	NS	NS	0.20	2.40	0.04	1.58	0.30	0.01	0.23
			1.45	4.37	0.20	55.86	2.92	20.00	0.93	16.12	0.29	0.02	0.34
TH	B	10	0.12	0.88	0.21	20.80	0.37	0.91	0.02	1.16	0.17	0.05	0.08

Appendix 3. 2003 American chestnut biomass data. Values means (top number) ± SE (bottom number). Where there are values without an SE, there was only one seedling in the plot. NS = No Standard Error. Mass (g), area (cm^2), height and length (m). ND = No Data.

Forest	Trmt	Plot	Total biomass	# of leaves	Leaf mass	Leaf area	Basal d	Stem height	Stem mass	Root length	Root mass	Fine root mass	Root: Shoot
			15.02	5.00	1.09	90.77	3.80	23.00	0.73	12.5	0.64	0.04	0.95
Z	C	1	0.75	1.35	0.17	37.75	0.58	4.20	0.28	2.90	0.28	0.02	0.07
			18.60	5.66	0.27	30.46	3.71	21.75	0.57	17.16	0.53	0.06	1.03
Z	C	2	0.36	1.40	0.15	9.69	0.42	2.56	0.15	1.74	0.14	0.03	0.05
			18.00	4.00	0.31	83.30	5.02	16.25	0.65	16.25	0.68	0.09	1.18
Z	C	3	0.23	0.57	0.07	23.52	0.27	5.15	0.10	1.84	0.04	0.05	0.14
			25.13	5.00	0.44	42.97	4.3	21.00	1.49	22.33	0.81	0.03	0.57
Z	C	4	0.74	1.15	0.25	8.39	0.30	4.04	0.68	1.20	0.29	0.01	0.35
			10.86	3.33	0.19	31.96	4.43	19.66	0.46	9.66	0.44	0.10	1.18
Z	C	5	0.55	0.88	0.09	19.08	0.92	1.76	0.16	1.45	0.25	0.07	0.19
			9.43	3.33	0.10	36.13	4.16	21.00	0.44	8.66	0.20	0.01	0.50
Z	C	6	0.12	0.66	0.04	12.46	0.44	1.15	0.06	0.33	0.02	0.06	0.03
			16.91	4.00	0.44	106.95	3.86	20.66	0.53	15.30	0.57	0.11	1.28
Z	C	7	0.35	NS	0.02	5.51	0.33	1.20	0.07	2.96	0.10	0.03	0.04
			16.61	5.20	0.25	56.99	4.10	19.00	0.63	14.80	0.8	0.04	1.46
Z	C	8	0.42	0.8	0.06	16.27	0.29	3.17	0.14	1.65	0.20	0.02	0.11
			19.62	5.00	0.36	116.59	4.00	25.00	0.64	18.00	0.57	0.04	0.96
Z	C	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			22.48	6.00	0.46	110.76	4.80	23.50	0.92	20	0.92	0.16	1.18
Z	C	10	0.27	0.08	0.08	18.59	0.10	0.10	0.10	1.02	0.02	0.10	0.14
			20.26	6.00	0.28	65.38	4.10	30.33	1.09	18	0.71	0.17	0.81
R	C	1	0.45	1.52	0.05	13.73	0.51	2.60	0.08	5.56	0.09	0.10	0.11
			24.56	5.16	0.53	119	4.05	22.83	0.87	21.75	1.24	0.16	1.59
R	C	2	0.26	0.47	0.08	19.35	0.29	1.44	0.23	2.22	0.24	0.05	0.44
			15.83	6.66	0.32	67.24	3.93	25.33	0.95	13.50	0.93	0.11	1.11
R	C	3	0.40	1.76	0.06	14.78	0.40	1.92	0.05	2.46	0.12	0.04	0.13
			13.44	5.66	0.15	40.6	4.13	18.66	0.48	12.33	0.37	0.10	0.98
R	C	4	0.22	0.88	0.08	21.81	1.25	2.12	0.15	3.44	0.11	0.04	0.23
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	C	5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			16.53	0.57	0.23	67.46	3.96	19.33	0.77	14.66	0.78	0.07	1.11
R	C	6	0.44	0.09	0.09	30.63	0.33	0.33	0.15	1.92	0.15	0.02	0.16
R	C	7	12.81	6.00	0.37	110.87	3.30	28.00	0.72	11.00	0.61	0.11	1.00

			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			14.29	1.00	0.02	6.43	1.40	15.00	0.13	14.00	0.08	0.05	1.03
R	C	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			18.99	7.00	0.41	130.65	3.90	15.50	0.52	17.00	0.84	0.24	2.08
R	C	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	C	10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			9.96	ND	0.16	43.70	3.20	19.50	0.35	9.00	0.43	0.02	1.27
TH	C	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			18.02	5.00	0.17	53.83	3.70	15.5	0.27	17	0.55	0.02	2.14
TH	C	2	0.85	0.18	0.18	6.93	0.76	5.29	0.24	2.60	0.41	0.01	0.06
			13.82	5.00	0.19	61.75	3.10	20.00	0.58	12.50	0.49	0.04	0.93
TH	C	3	0.51	0.16	0.16	57.21	0.43	2.29	0.13	1.04	0.19	0.04	0.20
			11.12	3.00	0.15	24.88	2.10	22.50	0.28	10.50	0.17	0.03	0.69
TH	C	4	NS	NS	NS	10.91	NS	NS	NS	NS	NS	NS	NS
			14.54	ND	ND	ND	2.60	17.00	0.30	14.00	0.23	0.01	0.80
TH	C	5	0.64	NS	NS	NS	1.3	5.5	NS	NS	NS	NS	NS
			15.48	6.00	0.15	65.49	5.90	23.00	0.73	14	0.50	0.08	0.80
TH	C	6	0.19	0.04	0.04	10.91	0.53	1.43	0.16	2.02	0.23	0.05	0.06
			12.82	5.33	0.09	35.55	3.43	23.00	0.47	12	0.23	0.01	0.54
TH	C	7	0.08	0.01	0.01	10.88	0.35	2.51	0.06	2.51	0.08	0.01	0.08
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	C	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	C	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			13.86	ND	ND	ND	2.70	21.00	0.31	13	0.43	0.03	1.46
TH	C	10	0.32	NS	NS	NS	0.18	2.39	2.37	2.31	0.12	0.06	0.54
			16.19		0.65	182.74	5.20	36.00	1.12	13.50	0.84	0.06	0.80
Z	T	1	0.85	7.00	0.26	65.16	0.70	7.00	0.24	2.50	0.32	0.19	0.12
			27.17	8.00	0.98	85.17	4.50	28.00	1.13	23.00	1.92	0.13	1.80
Z	T	2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			36.98	10.80	1.24	308.39	5.44	31.00	1.22	32	1.80	0.70	2.04
Z	T	3	0.71	1.46	0.40	63.35	0.44	1.22	0.16	3.96	0.50	0.21	0.34
			20.87	6.40	0.63	140.67	4.70	20.80	0.76	18	0.97	0.48	1.90
Z	T	4	0.68	1.72	0.19	4.22	0.49	2.13	0.16	1.37	0.24	0.13	0.19
			28.30	13.50	2.32	407.88	7.40	49.00	3.10	20	2.20	0.67	0.93
Z	T	5	1.70	0.50	0.47	73.86	0.60	8.00	0.39	2.00	0.91	0.07	0.20
			26.63	16.00	1.42	331.28	6.50	42.00	2.13	21	1.79	0.27	0.96
Z	T	6	1.67	4.00	0.41	74.56	0.52	10.00	0.52	2.00	0.79	0.05	0.17

			31.09	14.50	0.65	229.38	5.20	28.50	1.21	26.50	1.63	1.08	2.24
Z	T	7	1.71	6.50	0.38	39.62	1.50	7.50	0.65	4.50	0.79	0.65	0.10
			25.76	7.00	0.56	139.04	4.94	25.10	0.88	23	1.12	0.19	1.49
Z	T	8	0.44	0.54	0.17	48.25	0.24	2.32	0.19	1.30	0.21	0.02	0.61
			28.69	9.33	1.09	244.29	5.10	34.66	1.37	24.33	1.45	0.43	1.37
Z	T	9	0.51	0.88	0.19	41.04	0.26	1.45	0.28	1.85	0.28	0.17	0.53
			33.43	5.00	0.29	75.65	4.20	23.66	0.68	31.66	0.55	0.23	1.15
Z	T	10	0.31	0.57	0.04	13.86	0.30	1.45	0.03	9.52	0.24	0.20	0.32
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			26.09	9.50	0.92	175.37	5.85	33.50	1.54	21.50	1.67	0.43	1.36
R	T	2	0.56	0.50	0.05	9.01	0.05	6.50	0.34	1.50	0.09	0.17	0.18
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			22.41	11.33	1.24	264.71	4.83	34.16	1.45	17.83	1.49	0.37	1.28
R	T	8	0.78	0.88	0.14	33.76	4.20	4.20	0.30	0.92	0.39	0.04	0.10
			17.95	6.50	0.38	85.47	4.83	30.16	1.54	14.50	1.14	0.39	0.99
R	T	9	1.23	0.50	0.22	42.13	1.13	9.94	0.88	3.27	0.29	0.18	0.35
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	T	10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			29.41	7.50	1.04	230.71	5.82	32.87	2.05	23	2.85	0.46	1.61
TH	T	1	1.69	2.21	0.36	72.22	0.35	2.10	0.37	3.93	0.83	0.21	0.22
			17.26	4.00	0.21	63.50	3.60	19.50	0.63	15.50	0.85	0.06	1.45
TH	T	2	0.57	2.00	0.15	44.79	0.10	0.50	0.02	1.50	0.33	0.001	0.48
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	T	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			18.84	7.00	0.40	102.55	4.20	37.00	1.57	15.50	1.19	0.18	0.87
TH	T	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			19.54	4.80	0.39	95.71	4.22	32.40	1.28	16.20	1.54	0.11	1.28
TH	T	5	0.53	0.73	0.06	15.34	0.26	3.96	0.16	4.25	0.33	0.02	0.28
TH	T	6	27.05	5.00	0.57	130.39	7.05	58.00	3.78	19.87	2.39	0.41	0.74

			2.18	2.90	0.39	87.30	0.88	7.47	1.03	4.78	0.72	0.15	0.04
			23.64	2.33	0.24	37.37	5.16	29.33	1.30	20.16	1.10	0.82	1.47
TH	T	7	1.10	0.33	0.06	11.47	0.92	3.47	0.45	3.65	0.28	0.32	0.08
			44.36	12.00	2.04	321.22	6.43	40.83	3.81	33.33	3.81	1.36	1.35
TH	T	8	4.98	5.85	1.26	103.38	0.93	1.58	1.09	10.92	1.81	0.94	0.32
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	T	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			19.05	ND	ND	ND	4.15	24	0.72	17.50	0.75	0.06	1.13
TH	T	10	0.34	NS	NS	NS	0.25	1.01	0.08	4.5	0.24	0.01	0.21
			21.93	11.00	0.58	118.21	4.53	30.66	1.05	19.00	1.01	0.28	1.22
Z	TB	1	0.97	6.00	0.29	62.13	0.49	2.84	0.28	2.30	0.41	0.11	0.14
			45.36	17.50	3.32	674.50	7.36	34.46	3.61	33.50	4.07	0.85	1.36
Z	TB	2	1.77	2.90	0.67	147.97	0.48	6.87	0.60	4.02	0.47	0.19	0.25
			29.21	12.80	1.53	293.74	6.54	36.00	1.62	23.80	1.79	0.45	1.38
Z	TB	3	2.10	2.80	0.71	122.46	0.75	5.89	0.66	1.49	0.62	0.17	0.36
			39.59	15.40	2.28	443.19	5.10	36.00	2.57	30.40	3.52	0.79	1.67
Z	TB	4	3.79	4.41	0.98	178.72	1.18	10.12	0.94	1.12	1.50	0.47	0.25
			25.92	14.50	0.72	145.87	4.97	31.25	1.38	22.00	1.45	0.36	1.31
Z	TB	5	0.87	3.70	0.21	37.39	0.73	6.62	0.41	3.08	0.31	0.03	0.64
			36.30	12.66	2.32	417.47	6.03	42.66	2.53	28.00	3.03	0.41	1.35
Z	TB	6	2.82	2.90	0.89	164.81	0.95	3.75	0.73	0.57	1.01	0.18	0.05
			32.86	15.80	1.56	293.42	5.46	28.60	1.58	26.60	2.66	0.45	1.96
Z	TB	7	1.31	2.08	0.32	56.90	0.57	4.80	0.31	3.52	0.64	0.07	0.20
			40.59	13.75	1.49	311.37	5.75	38.25	1.94	34.00	2.61	0.54	1.62
Z	TB	8	1.06	2.17	0.23	43.35	0.60	4.98	0.49	3.74	0.37	0.14	0.28
			24.71	11.00	0.99	181.41	6.00	28.66	1.58	20.00	1.71	0.42	1.35
Z	TB	9	0.87	0.57	0.08	22.38	0.32	5.23	0.42	2.00	0.36	0.12	0.12
			35.43	13.80	1.70	344.29	5.92	41.60	2.71	27.80	2.93	0.28	1.18
Z	TB	10	1.88	2.78	0.40	76.14	0.64	6.56	0.73	3.63	0.72	0.09	0.08
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	TB	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			46.64	32.75	3.17	757.44	8.02	63.75	6.25	31.62	4.50	1.08	0.89
R	TB	2	3.04	4.92	0.56	238.28	0.94	11.50	1.79	7.64	0.73	0.32	0.33
			37.56	14.25	2.06	348.25	5.86	41.00	2.51	29.00	3.18	0.80	1.59
R	TB	3	2.15	3.14	0.64	142.35	0.40	5.26	0.51	6.11	0.86	0.20	0.15
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	TB	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	TB	5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

			36.64	13.66	1.52	364.03	5.56	53.50	2.67	29.83	2.28	0.32	0.97
R	TB	6	1.62	3.17	0.45	77.79	0.24	6.33	0.51	3.90	0.65	0.12	0.09
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	TB	7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	TB	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	TB	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			18.51	3.66	0.18	47.81	3.05	21.25	0.44	17.25	0.58	0.04	1.427
R	TB	10	0.09	0.88	0.07	140.81	0.08	1.85	0.06	4.00	0.14	0.01	0.43
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	TB	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			26.13	3.20	0.21	48.17	3.96	24.80	0.85	23.20	1.62	0.22	2.15
TH	TB	2	0.73	0.86	0.09	15.22	0.34	2.90	0.20	5.20	0.38	0.12	0.19
			25.71	5.00	0.63	170.51	4.30	33.50	1.23	22.00	1.74	0.13	1.52
TH	TB	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	TB	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			14.89	ND	ND	ND	3.40	20.00	0.44	14.00	0.44	0.01	1.03
TH	TB	5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			26.99	2.50	0.35	81.56	5.05	36.00	1.77	22.50	1.76	0.58	1.32
TH	TB	6	0.96	0.64	0.13	29.48	0.72	5.52	0.47	2.59	0.26	0.24	0.21
			18.12	3.00	0.22	64.14	4.10	32.50	0.86	16.00	0.98	0.05	1.20
TH	TB	7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	TB	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			38.83	5.00	1.01	253.85	7.50	ND	2.59	33.00	1.98	0.25	0.86
TH	TB	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			16.27	2.50	0.14	42.99	3.50	24.75	0.55	14.75	0.38	0.44	1.48
TH	TB	10	0.15	1.50	0.09	35.61	0.10	1.75	0.03	4.25	0.07	0.36	0.10
			33.68	15.60	1.88	374.51	6.48	38.00	2.02	27.40	1.96	0.41	1.17
Z	B	1	1.57	3.70	0.53	109.3	0.89	4.50	0.51	4.71	0.51	0.12	0.17
			16.32	3.50	0.10	19.46	3.65	16.50	0.32	15.50	0.32	0.07	1.25
Z	B	2	0.06	1.50	0.02	3.5	0.35	0.50	0.03	2.50	0.002	0.001	0.08
			21.53	3.00	0.26	74.07	4.76	29.66	0.89	19.66	0.63	0.07	0.79
Z	B	3	0.31	0.57	0.12	35.86	0.39	3.17	0.08	4.84	0.15	0.03	0.10
			24.48	6.50	0.33	69.95	4.82	25.50	0.81	22.25	0.94	0.14	1.33
Z	B	4	0.43	2.02	0.10	26.83	0.31	3.57	0.17	2.78	0.23	0.06	0.38
		5	19.56	6.50	0.56	123.85	4.60	24.00	0.85	17.00	0.96	0.18	1.35

Z	B		1.24	1.50	0.43	97.15	1.00	2.00	0.24	4.00	0.59	0.02	0.40
			21.51	6.66	0.47	107.14	4.43	31.66	1.05	19.00	0.90	0.07	0.93
Z	B	6	0.39	1.45	0.18	41.65	0.23	0.66	0.06	1.52	0.17	0.02	0.13
			27.48	15.60	1.03	265.83	5.70	39.00	2.10	22.60	1.26	0.47	0.82
Z	B	7	1.11	2.11	0.32	79.45	0.79	4.86	0.48	1.63	0.20	0.17	0.12
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z	B	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			22.91	12.66	0.72	185.44	5.53	30.33	1.12	19.66	1.26	0.12	1.23
Z	B	9	1.13	2.02	0.27	59.44	0.68	3.92	0.35	5.20	0.46	0.05	0.17
			16.30	4.00	0.27	81.53	4.10	26.00	0.78	14.60	0.57	0.06	0.81
Z	B	10	0.47	0.89	0.12	36.22	0.28	4.04	0.19	2.29	0.16	0.02	0.06
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	B	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			34.91	13.25	1.55	332.18	5.10	35.12	1.86	28.50	2.68	0.31	1.61
R	B	2	0.59	0.75	0.17	33.26	0.31	2.23	0.28	3.92	0.28	0.06	0.18
			26.78	12.40	0.91	291.78	5.52	33.40	1.53	22.00	2.04	0.29	1.53
R	B	3	1.34	2.54	0.37	68.97	0.34	1.63	0.33	1.04	0.59	0.09	0.12
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	B	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			14.98	8.00	0.44	88.50	3.66	23.50	0.74	12.66	0.96	0.16	1.52
R	B	5	1.05	2.80	0.19	40.17	0.52	4.44	0.32	2.60	0.48	0.03	0.38
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R	B	6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			19.25	11.50	1.09	237.87	6.00	34.50	1.99	14.75	1.28	0.12	0.70
R	B	7	1.75	4.50	0.65	120.0	2.10	6.50	0.80	7.55	0.30	0.04	0.14
			24.00	10.25	0.62	173.50	4.07	28.12	0.84	20.87	1.35	0.30	1.95
R	B	8	0.62	2.17	0.13	35.13	0.36	3.50	0.18	0.96	0.16	0.14	0.19
			20.21	5.50	0.72	82.71	3.37	17.12	1.03	17.12	1.26	0.06	1.27
R	B	9	1.08	1.19	0.32	29.31	0.42	3.24	0.49	2.90	0.28	0.01	0.48
			15.82	1.50	0.06	12.91	4.10	23.50	0.93	14.00	0.77	0.06	0.88
R	B	10	0.59	NS	NS	NS	0.70	3.5	0.36	3.00	0.23	0.04	0.07
			18.30	2.00	0.02	8.10	2.90	19.50	0.35	17.50	0.42	0.01	1.21
TH	B	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			8.14	1.00	ND	4.59	2.70	17.25	0.32	7.50	0.26	0.05	0.99
TH	B	2	0.06	NS	NS	NS	0.30	0.30	0.01	0.50	0.02	0.02	0.01
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	B	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			19.40	2.00	0.16	45.01	3.90	22.66	0.73	17.33	0.98	0.19	1.60
TH	B	4	0.50	NS	NS	NS	0.20	1.45	0.05	4.66	0.31	0.03	0.31

			16.92	1.33	0.05	16.24	3.90	24.00	0.87	15.16	0.70	0.12	0.94
TH	B	5	0.13	1.00	0.03	7.90	0.32	0.76	0.09	3.08	0.08	0.04	0.15
			24.59	1.33	0.08	21.23	3.43	20.33	0.51	22.83	1.01	0.14	2.25
TH	B	6	0.10	1.00	0.08	29.41	0.18	0.88	0.07	1.58	0.13	0.04	0.48
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	B	7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	B	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TH	B	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
			20.55	3.00	0.17	56.91	3.16	21.50	0.51	19.16	0.55	0.13	1.34
TH	B	10	0.08	1.0.0	0.07	25.21	0.29	0.76	0.05	0.83	0.07	0.05	0.23