Diameter growth of *Acer grandidentatum* (Bigtooth maple) in isolated central Texas populations

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ABSTRACT

Acer grandidentatum Nutt. (Bigtooth maple, Aceraceae) populations are mostly found in the mountains of western North America. There are a few isolated populations in western and central Texas. We measured annual diameter growth of plants that were found in isolated populations in deep canyons of the Albert and Bessie Kronkosky State Natural Area in central Texas. Plants sampled ranged in size from 17.57 mm to 232.41 mm in basal diameter. We used dendrochronological techniques to estimate diameter growth which was 2.50 mm basal diameter/y and comparable to some other deciduous and evergreen woody plants. Growth in diameter was a linear function with stem age increasing as basal diameter increased (y= 0.40x, R^2=0.85, P < 0.0001). The largest tree found was estimated to be 113 years old. *Acer grandidentatum* growth suggests it is not an early successional sun species but a mature community understory shade species. The age-diameter function will be used to estimate the age of *A. grandidentatum* plants in a future ecological study to determine recruitment of *A. grandidentatum* into isolated populations in central Texas including the Albert and Bessie Kronkosky State Natural Area. Published on-line www.phytologia.org *Phytologia 98(3): 232-240 (July 6, 2016).* ISSN 030319430.

KEY WORDS: basal diameter, mean annual growth rate, conservation, ABK, Albert and Bessie Kronkosky State Natural Area, dendrochronology

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Acer grandidentatum Nutt. (Bigtooth maple, Aceraceae) populations occur in a wide range of montane habitats, especially protected canyons across western North America (Little 1972; USDA 2016). They are found at various elevations, soil depths, soil types, moisture regimes, and with a number of different plant species (see Gehlbach and Gardner 1983; Nelson Dickinson and Van Auken 2016). In western Texas, there are scattered, isolated populations of *A. grandidentatum* in the Chisos, Davis and Guadalupe mountains (Little 1972; USDA 2016). In central Texas, isolated *A. grandidentatum* populations are mostly found in steep, sheltered canyons of the Edwards Plateau physiographic region (Nelson Dickinson and Van Auken 2016).

The most well-known populations of *A. grandidentatum* in central Texas are in Lost Maples State Natural Area (McCorkle 2007; Heidemann 2011). However, in 2011 Texas Parks and Wildlife acquired the approximately 1520 ha (=3757 ac) Albert and Bessie Kronkosky property, known as the 3K ranch, now called the Albert and Bessie Kronkosky State Natural Area (Figure 1). There are a number of *A. grandidentatum* populations in the various canyons present in this area (Figure 2A). The understory of the *A. grandidentatum* communities was fairly open (Figure 2B). It is possible that the number of *A.*

grandidentatum trees at the Albert and Bessie Kronkosky State Natural Area exceeds the number found at Lost Maples State Natural Area, although the specific density characteristics of either population are unknown.

There are few studies of outlier populations of *A. grandidentatum* (Gehlbach and Gardner 1983; Nelson Dickinson and Van Auken 2016). Gas exchange rates of *A. grandidentatum* suggest it is a shade species (Nelson Dickinson 2011; USDA 2016). There are no studies that we have identified concerning growth rates of mature *A. grandidentatum* plants. There are a few studies of *A. saccharum* germination and seedling growth, but few concerning growth rates of mature trees (Duchesne et al. 2002; Watmough 2002; Duchesne et al. 2003). Most of the studies of *A. saccharum* were carried out in the northeastern U.S. or southeastern Canada. The rates of recruitment of juvenile *A. grandidentatum* into these isolated mature populations in central Texas are unknown. *Acer grandidentatum* trees flower and produce seed, and seed germination and seedling establishment is occurring (personal observations), which should lead to successful population regeneration. However, long term endurance of juvenile maples has not been observed at the Lost Maples State Natural Area (Nelson Dickinson and Van Auken 2016) or the Albert and Bessie Kronkosky State Natural Area and recruitment of juveniles into the adult population is hearsay at best. Furthermore, the timing and date of the last recruitment are unknown.

PURPOSE

The purpose of this study was to determine the diameter and age of *A. grandidentatum* plants in the Albert and Bessie Kronkosky State Natural Area and to estimate the mean annual growth rate of *A. grandidentatum* in these central Texas populations.

METHODS

The study site was in the Albert and Bessie Kronkosky State Natural Area in and around the “Tin Cup Canyon” (Figure 1), which is in the Edwards Plateau Physiographic region of Texas (approximately 29^{o}44’25”N, 98^o 50’ 18”W). The study area was a woodland near an intermittent stream at the bottom of “Tin Cup Canyon” and on adjacent slopes of mostly north facing side canyons. Domestic grazing was the main industry of the general area, but in 1998 a 2.4 m high fence (deer fence) was constructed and grazing was halted in the Natural Area (Carpenter and Brandimarte 2014). For sampling, we identified standing dead and fallen *A. grandidentatum* plants in this area. The elevation is 484-614 m above mean sea level. Canyon bottoms have relatively deep calcareous silty clay soil, a Mollisol overlying limestone bedrock (SCS 1977). The soil series in the area are Eckrant-Rock outcrop associations, steep, consisting of clayey-skeletal, smectitic, thermic lithic haplustolls (SCS 1977). Mean annual temperature in the study area is approximately 18.3^{o}C, ranging from near 0.7^{o}C to 34.1^{o}C, and mean annual precipitation is highly variable but approximately 72.4 cm/year with very little in July and August with May and September being wettest (World Climate 2011). Unknown densities of white-tailed deer and wild hogs are present in the Natural Area while densities of approximately one deer/5 ha are reported in adjacent regions (Armstrong and Young 2000; Fulbright and Ortega-S. 2005).

Tree sampling was conducted from March through May 2016. In the canyons where *A. grandidentatum* populations were found, we haphazardly selected samples. Samples were standing dead and fallen trees and had a variety of different diameters. Tree sections were collected from near the base. Samples were numbered and taken to the laboratory for processing. In the laboratory, collected stems were cut into thinner slices and air dried. After drying, slices were sanded thoroughly using coarse (p-grade 100), medium (p-grade 150) and then fine (p-grade 220) sandpaper until the annual rings could be clearly observed (Figure 3A). Earlywood, latewood, vascular rays and pith could be easily seen in many of the stems. Some samples had heart-rot (Figure 3B) and some had insect holes or borings and could not be used (Figure 3C). Many of the larger down stems that we cut could not be aged because of extensive rot and insect damage (Figure 3C, some were worse and are not shown). Basal diameter of smaller stems was measured to the nearest 0.01 mm with a caliper (Mitutoyo-digimatic) in two perpendicular directions across the stem and averaged, while large stems were measured with a tape measure in two perpendicular directions and averaged. Visual age of samples was determined by counting the annual rings with a 20X magnifying glass and a 40X binocular microscope (Fritts 1976; Shen et al. 2016). The distribution of tree age versus diameter was examined and then regressed. The best fit regression equation with the 95 % confidence intervals are presented. The growth rate for the *A. grandidentatum* trees was calculated as the inverse of the slope of the regression line (1/0.40 in the current example).

RESULTS

A map of the location of the Albert and Bessie Kronkosky State Natural Area, the location in the state of Texas and the location in Kendall and Bandera Counties along state highway 46 is shown (Figure 1A&B). The study area included steep sided canyons shown in part of a topographic map with the approximate location of the research area indicated with a red oval, with the dark green line indicating the northern Natural Area boundary (Figure 1C). An aerial photograph (Figure 1D) shows the approximate study area with the same northern boundary (fence) and some of the *A. grandidentatum* trees in their fall colors, with the red oval showing the study area. A picture from ground level looking northwest over “Tin Cup Canyon” (Figure 2A) where many *A. grandidentatum* trees were found is presented, while the second photograph (Figure 2B) is a picture below the *A. grandidentatum* canopy depicting many of the mature tree stems and the very open nature of the community.

Many cross sections of the *A. grandidentatum* trees were quite clear (Figure 3A) and usually showed the pith, vascular rays, earlywood, latewood and the annual rings, and when the bark was intact the cambium, inner and outer bark could be identified (Figure 3B). Various stems had some rot, including heart rot, and some stems encountered could not be used and were discarded because of rot, numerous insect borings in the stem (probably beetles) and missing bark (Figure 3C). An X-Y plot of stem diameter in mm and age in years is also presented (Figure 4). Shown in the figure are 26 age/diameter points of various sized *A. grandidentatum* trees. The regression is a significant linear function with R^2=0.85 and $p<0.0001$. The equation for the line is $y= 0.40x$ when the origin is forced through zero. The figure also shows the upper and lower 95 % confidence interval for the data. The growth rate for the *A. grandidentatum* trees was calculated as 2.50 mm/y.

DISCUSSION

All of the *Acer grandidentatum* trees aged and measured in the present study were in or around the “Tin Cup Canyon” of the Albert and Bessie Kronkosky State Natural Area (Figure 1). A moisture gradient may have been present and a possible cause of some of the variation in diameter, but was not examined. Seedlings of *A. grandidentatum* were present within the communities examined, but very few saplings or juvenile trees were observed, which suggested that some biotic or abiotic factor or factors prevented seedlings from being recruited into the canopy (personal observation). The same seems to be true for *A. saccarium* in central Missouri (Belden and Pallardy 2009). Similar studies reported lower mortality and greater growth in the understory for *A. saccarium* and other species if herbivory was prevented (Côté et al. 2004; Russell and Fowler 2004; Belden and Pallardy 2009; Leonard and Van Auken 2013; Nelson Dickinson and Van Auken 2016). Examining herbivory was not part of the present study; however, herbivory has been reported as a cause of recruitment failure for other deciduous species in the Edwards Plateau Physiographic Region (Van Auken 1988; Fuhlendorf et al. 1997; Russell et al. 2001; Russell and Fowler 2004).

We wanted to demonstrate the relationship between age and size (diameter) of *A. grandidentatum* in the Albert and Bessie Kronkosky State Natural Area (Figure 4). We hope to use this information to show the recruitment history of this species in the Natural Area. This will require knowing the age-size frequency distribution of the various populations of *A. grandidentatum*, which are unknown at this time. Understanding recruitment of juveniles into the adult population in existing woodland and forest communities has proven difficult to understand. However, a large number of papers have been written about the topic (see Baker et al. 2005). Factors that control recruitment have also been difficult to understand as have the factors that control the growth of individual plants below the canopy of an adult population. Light levels are certainly important, but soil resources, neighbors and herbivores are important as well (see McKinley and Van Auken 2005; Van Auken 2009).

The age and diameter of *A. grandidentatum* could be a sigmoid relationship, but much of that curve could be linear depending on the ages of the plants sampled. In a previous study of *A. saccharum* (Duchesne et al. 2003), trees that were between 111 and 135 years old, considerable variation in age and size was found. In addition, many of the trees in their study couldn't be aged because of heart-rot or other unidentified factors causing variability in growth. In the present study we noted considerable heart-rot and the smallest individuals measured were not zero age, but 4-5 years old and approximately 17 mm in diameter, suggesting our methods may have missed the first several years of growth.

We believe that the possible decreased density of *A. grandidentatum* and other deciduous species in favor of increased density of *Juniperus ashii* reported at Lost Maples State Natural Area (Nelson Dickinson and Van Auken 2016) may be reflective of wider trends reported across North American woodlands. These studies have shown that the presence of predators is critical for maintaining mature plant populations (Beschta and Ripple 2009; Abrams and Johnson 2012; Ripple et al. 2014). *Acer grandidentatum* growth is about 33 % of the growth of *Pinus ponderosa* a gymnosperm an early successional sun species (Table 1). Its growth is greater than *Quercus gambelii* and *Larix olgensis* a deciduous species and a gymnosperm species respectively (Ryniker et al. 2006; Shen et al. 2016). *Acer grandidentatum* seems to be an understory species and a late successional species (Nelson Dickinson and Van Auken 2016).

Table 1. Growth rates of two conifers (gymnosperms) and two deciduous angiosperms.

Species	Age(y)	Growth Rate(mm/y)	Date Source
Pinus ponderosa	15-130	7.654	Personal observations
Larix olgensis	145-397	1.595	Shen et al. (2016)
Quercus gambelii	109-137	1.237	Ryniker et al. (2006)
Acer grandidentatum	4-113	2.500	This paper

We will use the age-diameter curve reported in the present study to demonstrate that recruitment failure for *A. grandidentatum*, which appears to be occurring, seems to be happening very early in the life cycle of *A. grandidentatum* in its Central Texas populations. This same phenomena is occurring for other woody angiosperms in this area and the cause is probably herbivory and the same for all of these central Texas woody species (Van Auken 1988; Fuhlendorf et al. 1997; Russell et al. 2001; Russell and Fowler 2004; Nelson Dickinson and Van Auken 2016).

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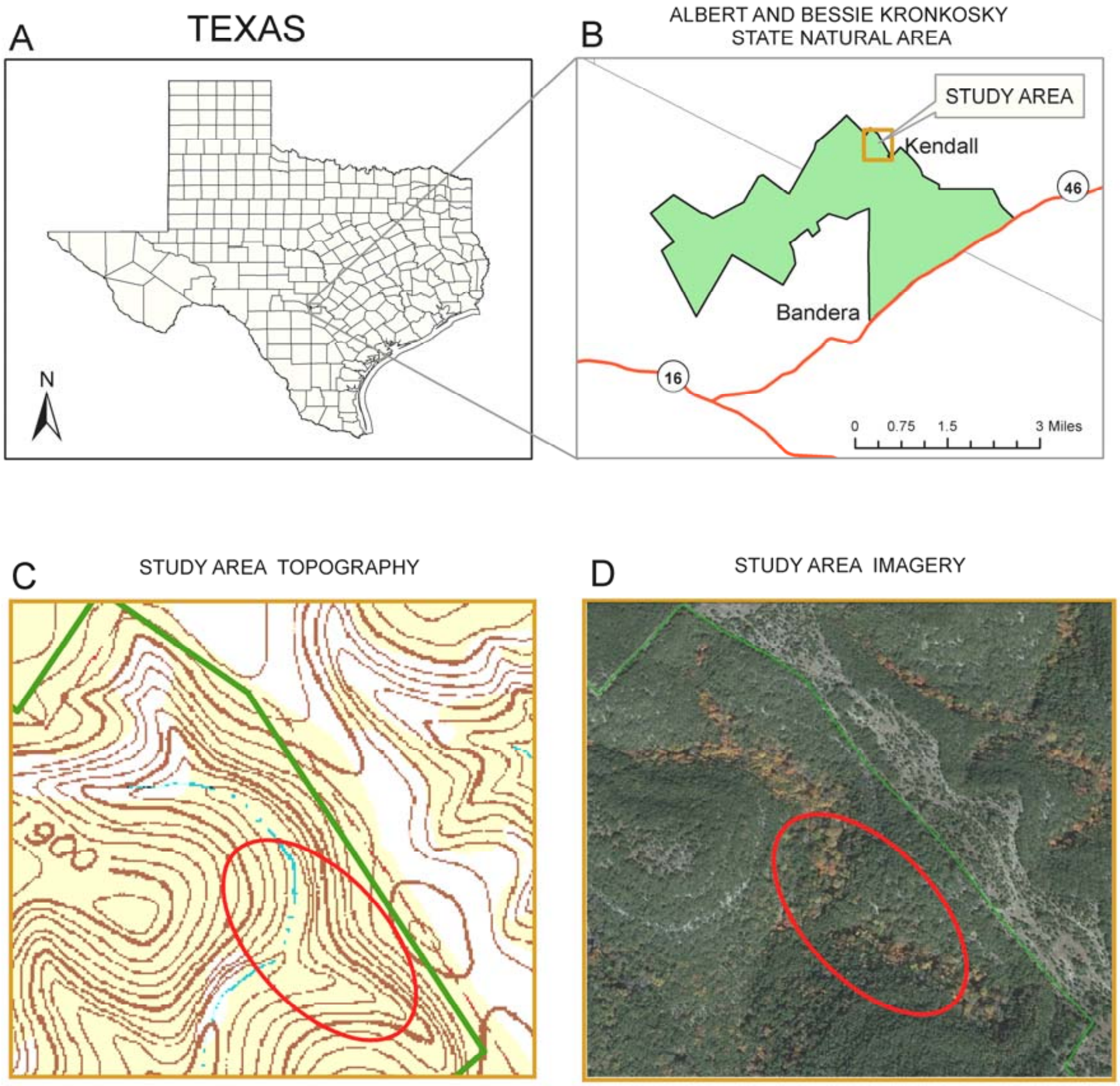


Figure 1. Map of research area in the Albert and Bessie Kronkosky State Natureal Area with (A) showing the location in the state of Texas. (B) Shows the location in Kendall and Bandera Counties along state highway 46. (C) Is part of a topographic map showing the approximate location of the study area red oval in the steep sided "Tin Cup Canyon" with the green or dark line depicting the northern boundary. (D) Is part of an aerial photograph showing the same northern boundary line (fence) with some of the bigtooth maples showing their fall colors and the red oval showing the approximate study area.

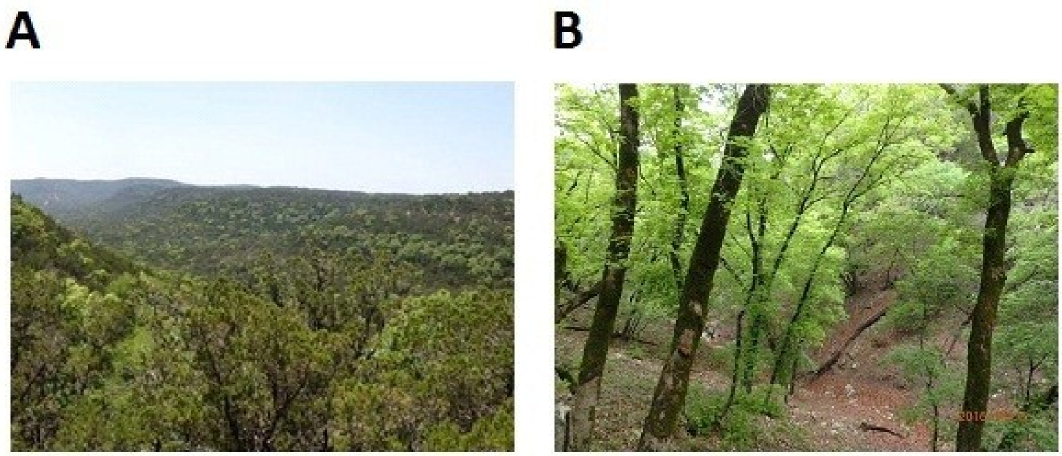
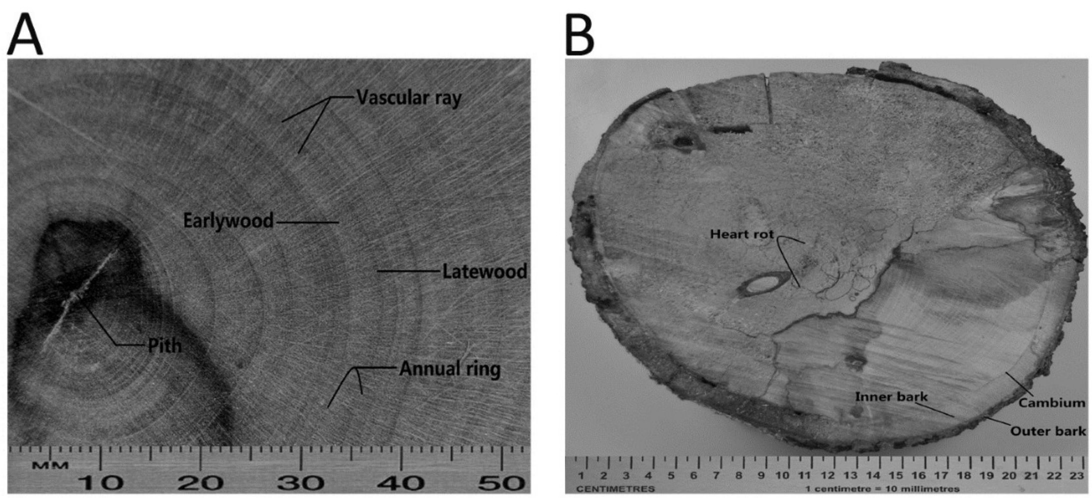


Figure 2. The first picture (A) shows a picture from ground level looking northwest over a canyon where many *A. grandidentatum* trees were found. The second photograph (B) is a picture below the *A. grandidentatum* canopy showing many of the mature tree stems and the very open nature of the community.



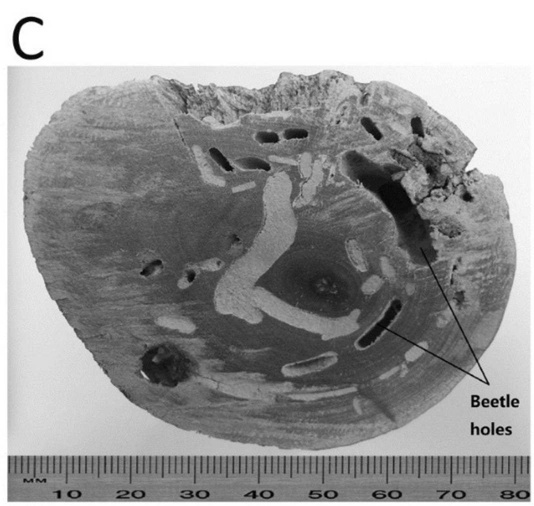


Figure 3. (A) This picture shows an intact stem cross-section with the pith, vascular rays, earlywood, latewood and a number of annual rings. (B) This picture shows a stem with heart rot, cambium, inner and outer bark. (C) This picture shows a completely dead stem with a number of insect holes in the stem (probably beetles) and the bark is missing. Note the scale (bottom) in all of the figures.

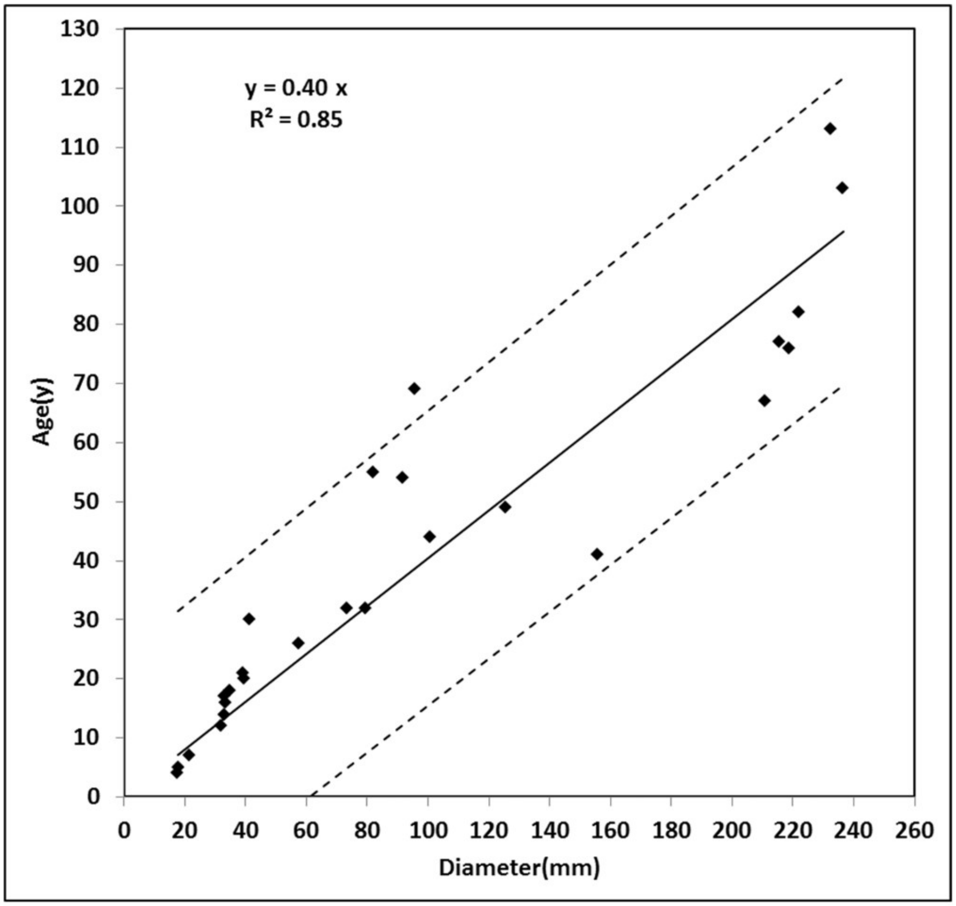


Figure 4. This figure represents a linear regression of age on diameter of the 26 samples of *Acer grandidentatum* trees measured. The two dashed lines stand for the upper and lower bounds of the 95% confidence interval for the regression. The mean value of the confidence interval for each bound is 24.22 units above or below the regression line.