Establishment and Growth of Transplanted Conifers in the Southern Great Plains[1]

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Abstract

Pinus spp. (pine) currently experience considerable pressure from numerous pests, diseases, and sometimes harsh climate of the Midwest and Great Plains thus jeopardizing the health of current windbreaks and landscapes. Four species of conifers, *Abies nordmanniana* (Nordmann fir), *Cupressus arizonica* (Arizona cypress), *Picea engelmannii* (engelmann spruce), and *Thuja* × 'Green Giant' ('Green Giant' arborvitae) were spring planted in a sandy loam soil to observe root and shoot growth during the initial 12 months following transplant. Whole plant (roots and shoots) harvests occurred monthly for examination and collection of growth data. Results indicate that *C. arizonica* exhibited rapid root and shoot growth throughout the growing season with increases in dry weight of 4800 and 6300%, respectively. In contrast, *P. engelmannii* exhibited a modest increase in root dry weight of 82% throughout the growing season while shoot growth was essentially non-existent. *Thuja* × 'Green Giant' exhibited significant increases in shoot (230%) and root (350%) growth throughout the growing season. *Abies nordmanniana* exhibited minimal yet significant shoot and root growth during the study, with dry weight increases of 13 and 55%, respectively. The data herein suggests that *C. arizonica* easily establishes following transplant because it rapidly initiates new root and shoot growth.

Index words: field production, landscape establishment, root growth, shoot growth, bare root.

Species used in this study: Arizona cypress (*Cupressus arizonica* Greene); Engelmann spruce (*Picea engelmannii* Perry ex Engelm.); 'Green Giant' arborvitae (*Thuja* × 'Green Giant' L.); Nordmann fir [*Abies nordmanniana* (Steven) Spach.]

Significance to the Nursery Industry

Four species of conifer, Nordmann fir, Arizona cypress, Engelmann spruce, and 'Green Giant' arborvitae were planted in a sandy loam soil to observe root and shoot growth during establishment. Results indicate that Arizona cypress exhibited extraordinary root and shoot growth capabilities throughout the growing season. While 'Green Giant' arborvitae was slow to resume growth after transplant, it maintained a steady rate of growth and had excellent survival rates. In contrast, Engelmann spruce and Nordmann fir exhibited a modest increase in root dry weight throughout the growing season; however, shoot growth was essentially non-existent. The data herein suggests that Arizona cypress easily transplants because it rapidly establishes new root and shoot growth following planting in difficult environments, making it a viable candidate for producers in the Midwest. Additional work is needed on the three other species to investigate optimal planting season for improved growth.

Introduction

Conifers are an integral component of most landscapes, be it rural or urban. In an urban environment conifers anchor the landscape design and provide winter interest and color as well as wildlife habitat. Conifers are used widely for screening of unsightly structures. In the rural environment conifers have been used for windbreaks and dust abatement along gravel roads. After the dustbowl of the 1930s windbreaks were promoted for their ability to slow winds in rural settings and to control erosion on adjacent fields (20). In Kansas, the primary conifer used for wind abatement, landscaping, and Christmas tree production is native *Juniperus virginiana* L. (eastern redcedar), which can be weedy when left unmanaged. Other options include non-native *Pinus strobus* L. (eastern white pine), *Pinus sylvestris* L. (scots pine), and *Pinus nigra* Arnold (Austrian pine). Currently *Pinus* spp. are experiencing considerable pressure from numerous pests, diseases, and the sometimes harsh climate of the Midwest and Great Plains thus jeopardizing the health of current windbreaks and landscapes. The most significant disease eliminating pine trees in Kansas is pine wilt. This disease complex consists of the pine wood nematode (*Bursaphelenchus xylophilus* [Steiner & Buhrer] Nickle) and members of the pine sawyer wood boring beetles (*Monochamus* spp.) (7). The nematode, which causes tree death, is vectored by the pine sawyer beetle when young beetles emerge from nematode infested trees and fly to healthy trees to feed. The nematode was first reported in the United States in 1929 but was not recognized as a destructive pathogen until 1979 in Columbia, MO, on Scots pine (4, 18). The nematode kills the host by feeding and reproducing in the xylem and the phloem, which disrupts the flow of water and nutrients throughout the tree. This disease is sometimes exacerbated by environmental stress. As a result of this disease and repeated environmental stress across the region, underutilized conifers that can withstand the environmental pressure of the Midwest and Great Plains and are resistant to pests and diseases are of utmost importance. However, a basic understanding of transplant success and ease of establishment will be required prior to widespread acceptance.

Root regeneration and elongation are integral processes that must precede shoot initiation to ensure survivability of transplanted trees (6, 10, 15). Initiation of shoot growth prior to root growth can lead to water and nutrient stress, thereby jeopardizing the success of the new plant (11, 14). For many conifers it is often the case that the shoot:root ratio (shoot dry weight ÷ root dry weight) declines during the first few years following transplant (9, 12). Drew and Ledig (2) showed

[1]Received for publication July 13, 2012; in revised form July 30, 2012. This research was funded in part by K-State Agricultural Experiment Station and the Kansas Department of Agriculture. Assistance from the technical staff of the K-State John C. Pair Horticultural Center technical staff is greatly appreciated. From a thesis submitted by J. Pool in partial fulfillment of the requirements for the M.S. degree.

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an inverse relationship between shoot and root biomass accumulation in *Pinus taeda* L. (loblolly pine). A greater percentage of total biomass was attributed to root production than to shoot production. Ledig et al. (9) also showed that *P. taeda* exhibited a tendency to increase aboveground biomass initially when water and nutrients are abundant to increase stored photosynthates. As biomass accumulates, a shift is then made to increase root biomass to gain balance between absorbing and transpiring surfaces. When water and nutrients are limiting, energy is directed toward roots. Conversely, when a need for photosynthates for growth exists, energy is directed toward shoot accumulation (19).

Timing of transplant has been widely documented for many species and recommendations vary significantly between and within genera. Richardson-Calfee et al. (13) observed differences in trunk diameter, tree height, and root growth prior to spring bud break in *Quercus rubra* L. (northern red oak) and *Quercus phellos* L. (willow oak). *Quercus rubra* transplanted in fall had more roots prior to bud break than trees transplanted in spring. However, there was little difference in tree height and trunk diameter. Conversely, *Q. phellos* transplanted in fall did have increased trunk diameter, with no difference in root growth. In other work, *Chionanthus virginicus* L. (fringe tree) failed to regenerate roots outside of the rootball until July, well after budbreak, for fall or spring transplanted trees (6). Even so, November transplanted *C. virginicus* accumulated the most total biomass compared to December or March transplanting. Other research suggests that as long as water and nutrients are not limited, many genera can be transplanted nearly anytime during the year (21, 22). These studies also showed that in Illinois twig and root growth was greatest when trees were transplanted in July with a tree spade. The authors attributed the results to warmer soil temperatures and available water and nutrients creating an environment conducive to root growth. When *Acer platanoides* L. (Norway maple) were planted during spring bud break the authors observed decreased root growth compared to later planting dates (May), yet resumed root growth similar to May transplants after one year of growth (21). Therefore, a better understanding of root and shoot growth periodicity of a species prior to planting may aid transplant success in difficult environments. Our objective was to investigate the root and shoot growth characteristics of selected conifer species for potential pine replacements for the southern Great Plains.

Materials and Methods

On April 7, 2010, 96 plants each of *Thuja* × 'Green Giant' ('Green Giant' arborvitae) (Botany Shop; Joplin, MO), *Cupressus arizonica* (Arizona cypress) (New Mexico state conservation seedling program, Santa Fe, NM), *Abies nordmanniana* (Nordmann fir) (Lawyer Nursery; Plains, MT), and *Picea engelmannii* (Engelmann spruce) (Lawyer Nursery) were planted into a Canadian-Waldeck fine sandy loam soil at the Kansas State University John C. Pair Horticulture Center (Haysville, KS). Prior to planting, the site was cultivated and leveled, and nitrogen (Urea 46N-0P-0K) was incorporated following a soil test recommendation (Servi-Tech Laboratories; Dodge City, KS) at a rate of 39 kg·ha^{-1} (36 lbs·ac^{-1}) and cultivated to a depth of 7.6 cm (3.0 in). *Cupressus arizonica* seedlings were grown in 164 ml (10.0 in^3) cone-tainers, which were removed at planting and the roots manually teased out of the root ball. *Abies nordmanniana* and *P. engelmannii* seedlings were bare root liners whose root systems were trimmed to a consistent length of 17.8 cm (7.0 in) prior to planting. *Thuja* × 'Green Giant' were rooted stem cuttings grown in peat pellets. The nylon stockings were removed from the root ball prior to planting. The seedlings were planted in six rows with 1.0 m (3.3 ft) in-row spacing and 3.0 m (10.0 ft) between-row spacing. All planting was done by hand and plants were watered immediately following planting. Freezing temperatures occurred the night following planting and slight freeze damage was observed on foliage of all species. *Cupressus arizonica* and *T.* × 'Green Giant' were staked with 1.2 m (4.0 ft) bamboo stakes to provide additional support. Drip irrigation was utilized to maintain soil moisture [Robert's RO-Drip 300 LPH·100 m^{-1} (0.40 GPM·100 ft^{-1}); San Marcos, CA]. Watering occurred weekly for 6 hr to achieve 18.0 liters·m^{-1} (4.75 gal·3.2 ft^{-1}) of water when precipitation was insufficient. Weed control was accomplished using oryzalin (United Phosphorous Inc., Trenton, NJ) applied after planting at a rate of 9.45 liters·ha^{-1} (4 qt·ac^{-1}) and directed applications of glyphosate (2%) as needed. Between row weed control was accomplished through clean cultivation. On the day of planting 10 plants of each species were harvested and measured for initial growth data utilizing the procedures described below (Table 1).

Whole plant harvest (roots and shoots) occurred every 28 days utilizing a skid-steer mounted U-blade [Bobcat Digger 91.4 cm (3 ft); West Fargo, ND] to obtain a standard size root ball. Once lifted, free soil was shaken loose and plants were placed in a polyethylene bag and transported to Throckmorton Plant Sciences Center, Kansas State University, Manhattan. Plants were held in a cooler at 6.7C (44.0F) with all data collection occurring within 21 days after harvest. Data included plant height, width 1 (at the widest point), width 2 (perpendicular to width 1), and stem caliper at the soil line were measured. Roots were then separated from the shoots and washed with dry weights of both obtained following drying to a constant weight at 65.0C (149.0F) in a forced air drying oven. A growth index (GI) was calculated

Table 1. Initial height (Ht), shoot dry weight (SDW), root dry weight (RDW), and caliper of *Cupressus arizonica*, *Picea engelmannii*, *Thuja* × 'Green Giant', and *Abies nordmanniana* at planting.

	C. arizonica	*P. engelmannii*	*T.* × 'Green Giant'	*A. nordmanniana*
Ht (cm)	32.9^z	38.2	35.9	29.3
SDW (g)	2.0	52.5	7.7	32.5
RDW (g)	0.7	15.2	2.2	14.8
Caliper (mm)^y	2.9	14.7	5.8	12.6

^{z}n = 10

^{y}Stem caliper was measure at soil line

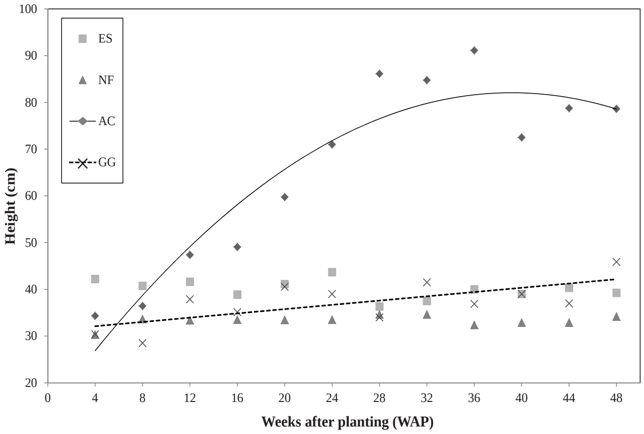

Fig. 1. Height (cm) of Arizona cypress (AC) ($y = -0.05x^2 + 3.5x + 13.6$; $R^2 = 0.89$), Engelmann spruce (ES), Nordmann fir (NF), and 'Green Giant' arborvitae (GG) ($y = 0.2x + 31.2$; $R^2 = 0.48$) throughout 48 weeks after planting (WAP).

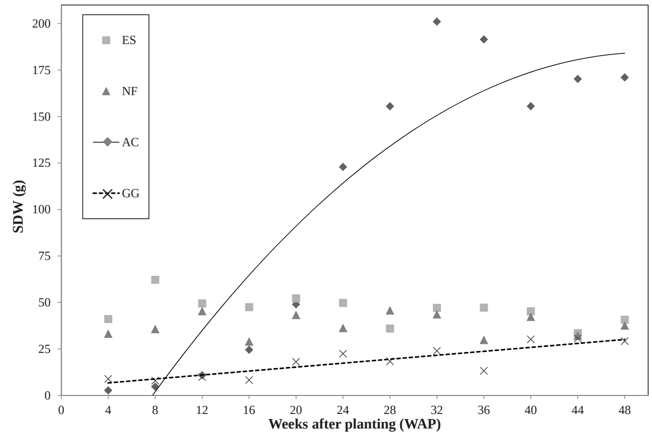

Fig. 2. Shoot dry weight (SDW) of Arizona cypress (AC) ($y = -0.10x^2 + 10.30x - 73.88$; $R^2 = 0.86$), Engelmann spruce (ES), Nordmann fir (NF), and 'Green Giant' arborvitae (GG) ($y = 0.53x + 4.58$; $R^2 = 0.76$) throughout 48 weeks after planting (WAP).

as (plant height + width 1 + width 2) ÷ 3. The experiment was a randomized complete block design with a split-plot arrangement of treatments. Whole plots consisted of time (harvest) and species were the sub-plot. There were two subsamples (plants) per species per harvest and the experiment was replicated four times (blocks) resulting in eight plants per species per harvest. Data were subjected to ANOVA and regression lines were fit where appropriate using SAS v. 9.1 (17).

Results and Discussion

There was a significant interaction between the main effects of species and harvest date for all measured variables. Plant height and shoot dry weight (SDW) responded similarly throughout the growing season (Figs. 1 and 2). Height of *C. arizonica* seedlings increased 165% from 34.3 cm (13.5 in) at planting to a maximum of 91.1 cm (35.9 in) by 36 weeks after planting (WAP). Height increase of *T.* × 'Green Giant' was less dramatic (51% increase); however, significant growth did occur from 30.4 cm (12.0 in) at planting to 45.9 cm (18.1 in) by 48 WAP. Shoot height of *P. engelmannii* [40.0 cm (15.7 in)] and *A. nordmanniana* [33.3 cm (13.1 in)] were unchanged throughout the year.

As expected, SDW followed a similar pattern as shoot height (Fig. 2). *Cupressus arizonica* exhibited an increase in SDW, from 2.7 g (0.1 oz) at planting to 201.1 g (7.1 oz) at 32 WAP (7300% increase) (Fig. 2). Shoot dry weight of *T.* × 'Green Giant' also increased from 8.9 g (0.3 oz) to a maximum of 30.6 g (1.1 oz) at 40 WAP (230% increase). Shoot dry weight of *P. engelmannii* [46.0 g (1.6 oz)] and *A. nordmanniana* [37.8 g (1.3 oz)] were unchanged throughout the year. These results were not entirely surprising given the indeterminate growth pattern of *C. arizonica* and *T.* × 'Green Giant'. So long as resources (soil moisture and fertility) are available and the temperature is acceptable for growth, the two species will continue growing throughout the season. However, *P. engelmannii* and *A. nordmanniana*, are species that have determinate growth habits therefore producing one flush of growth per year.

Growth index (GI) of *C. arizonica* and *T.* × 'Green Giant' increased (145 and 36.0%, respectively) throughout the growing season (Fig. 3) which was expected based on height and SDW increases. However, GI of *A. nordmanniana* was unchanged and that of *P. engelmannii* decreased. The decrease in GI of *P. engelmannii* is likely an artifact of increased variability due to fewer samples per harvest from plant death. The rapid increase of *C. arizonica* shoot growth may be associated with an inherent trait to assist in avoiding competition while producing an abundant root system to exploit soil resources (5, 23). In a study by Grimes (5), *Ailanthus altissima* (Mill.) Swingle (tree of heaven) exhibited rapid shoot growth that allowed the plant to avoid shading by competitors. *Cupressus arizonica* is native to, and well adapted to, drought prone regions. In the current study, this species was not subjected to prolonged drought conditions and therefore utilized its resources for rapid growth.

Root growth of *C. arizonica* initiated prior to the first harvest (4 WAP) and by the final harvest (48 WAP) had reached a depth greater than 1.0 m (39 in). It has been documented

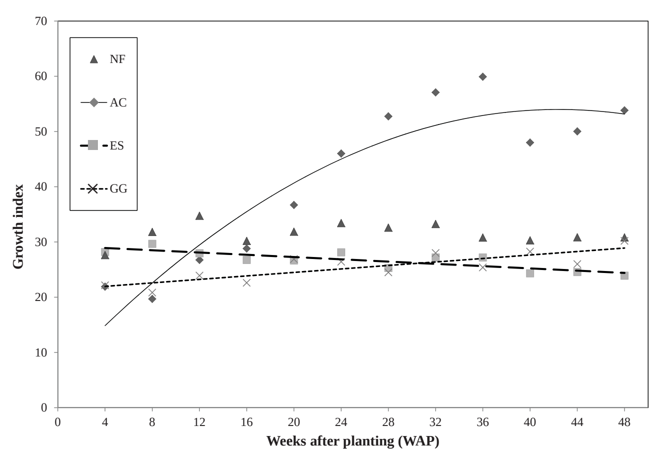

Fig. 3. Growth index [(width + perpendicular width + height) ÷ 3] of Arizona cypress (AC) ($y = -0.03x^2 + 2.25x + 6.26$; $R^2 = 0.88$), Engelmann spruce (ES) ($y = -0.10x + 29.32$; $R^2 = 0.69$), Nordmann fir (NF), and 'Green Giant' arborvitae (GG) ($y = 0.16x + 21.33$; $R^2 = 0.68$) throughout 48 weeks after planting (WAP).

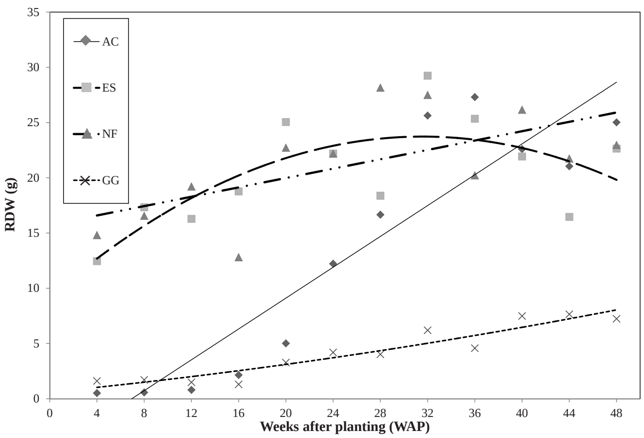

Fig. 4. Root dry weight (RDW) of Arizona cypress (AC) ($y = 0.70x – 4.85$; $R^2 = 0.84$), Engelmann spruce (ES) ($y = –0.01x^2 + 0.92x + 9.25$; $R^2 = 0.54$), Nordmann fir (NF) ($y = 0.21x + 15.74$; $R^2 = 0.40$), and 'Green Giant' arborvitae (GG) ($y = 0.00x^2 + 0.10x + 0.60$; $R^2 = 0.89$) throughout 48 weeks after planting (WAP).

that the time to initiation of new root growth is an excellent predictor of a species' ability to successfully transplant (6, 15, 23). Root dry weight (RDW) of *C. arizonica* increased by 5300%, from 0.51 g (0.02 oz) at planting to 27.3 g (1.0 oz) at 36 WAP (Fig. 4). The ability of *C. arizonica* to exploit favorable conditions and rapidly increase root mass may explain some of its known drought tolerance. New root growth of *T.* × 'Green Giant' was not observed until 16 WAP with a total increase of 375% at 44 WAP. *Abies nordmanniana* and *P. engelmannii* had similar patterns of root regeneration with new root growth beginning by 8 WAP and ceasing by 24 WAP resulting in increases of 90 and 135%, respectively. Overall, each of the species substantially increased their root mass throughout the growing season. However, in the case of *A. nordmanniana* and *P. engelmannii* roughly doubling the root mass may not be sufficient in a stressful environment.

Shoot to root ratio (SDW:RDW) of *C. arizonica* increased rapidly (268%) after planting due to rapid shoot expansion relative to root growth in early spring (4 to 12 WAP) but decreased with increasing root growth throughout the summer and into fall resulting in a decrease of 68% from 12 WAP to 48 WAP (Fig. 5). Above ground biomass was approximately 90% of total plant dry weight throughout the entire study (data not shown). Similar research by Ledig et al. (9) on *P. taeda* (loblolly pine), a similar semi-determinant growth species, showed that shoot growth was active during the spring when soil moisture was adequate and temperatures were ideal, then root growth resumed a more dominant role as water became limiting. *Thuja* × 'Green Giant' followed a similar pattern to *C. arizonica* with an initial SDW:RDW increase of 56% at 12 WAP followed by a decline of 54% at 48 WAP. *Picea engelmannii* and *A. nordmanniana* both had declines in SDW:RDW (46 and 28%, respectively), which is expected for a species with one flush of shoot growth in the spring followed by several weeks of root growth.

Stem caliper is often positively correlated with root growth (1, 3, 16). In the current study, caliper and RDW followed similar trends. As with the other growth measurements, caliper of *C. arizonica* increased rapidly (380%) from 3.1 mm (0.1 in) at planting to 14.9 mm (0.6 in) at 48 WAP (Fig. 6). *Picea engelmannii* and *T.* × 'Green Giant' caliper increased similarly to RDW with maximum increases of 24 and 72%, respectively. However, *A. nordmanniana* failed to increase stem diameter during the study [10.1 mm (0.4 in)].

Data herein suggests that *C. arizonica* (99% survival) rapidly establishes a robust root system and produces considerable shoot growth in a single season. These traits along with its known drought and heat tolerance make this species an ideal candidate for the lower Midwest and Great Plains regions. *Thuja* × 'Green Giant' (92% survival) is known for its rapid growth and local plantings have been successful. However, in the current study, growth of this species was less than anticipated. Perhaps this species requires a season to establish prior to resuming a rapid growth habit. *Picea engelmannii* (65% survival) and *A. nordmanniana* (83% survival) did not produce any shoot growth and root growth was minimal. In many instances, these species did not acclimate to the summer heat and the root system was insufficient to

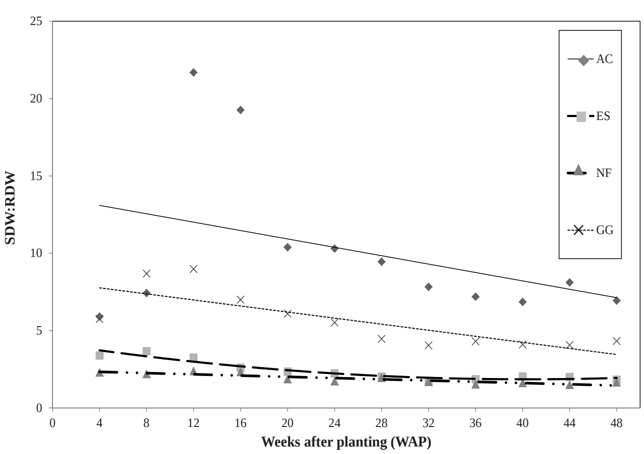

Fig. 5. Shoot dry weight (SDW):root dry weight (RDW) of Arizona cypress (AC) ($y = –0.14x + 13.64$; $R^2 = 0.15$), Engelmann spruce (ES) ($y = 0.00x^2 – 0.11x + 4.16$; $R^2 = 0.91$), Nordmann fir (NF) ($y = –0.02x + 2.41$; $R^2 = 0.78$), and 'Green Giant' arborvitae (GG) ($y = –0.10x + 8.16$; $R^2 = 0.63$) throughout 48 weeks after planting (WAP).

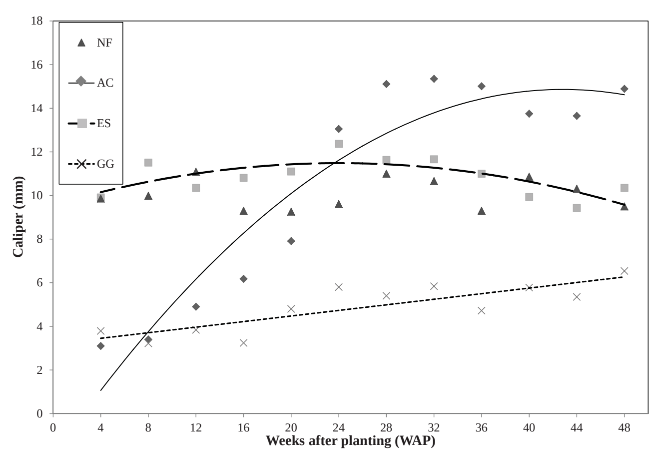

Fig. 6. Caliper of Arizona cypress (AC) ($y = –0.01x^2 + 0.78x – 1.92$; $R^2 = 0.90$), Engelmann spruce (ES) ($y = –0.00x^2 + 0.16x + 9.57$; $R^2 = 0.50$), Nordmann fir (NF), and 'Green Giant' arborvitae (GG) ($y = 0.06x + 3.20$; $R^2 = 0.69$) throughout 48 weeks after planting (WAP).

sustain the plant. Planting check (transplant shock) has been observed in numerous species of *Picea* sp. Mill.(spruce) with severity lasting from one up to 15 years (12). Laing (8) attributed transplant shock to damage of the root system at planting which inhibits the absorption of water and nutrients. Both of these species (*P. engelmannii*, *A. nordmanniana*) can be successfully grown in the southern Great Plains region, however, more research regarding planting and establishment may be needed.

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