ranged from small necrotic spots on the leaves to plant death. Symptoms were most pronounced in plants dipped in Vapor Gard, with a mortality rate of 40%. Necrotic leaf spots occurred in all antitranspirant treatments, but none of the other treatments resulted in significant mortality.

WATER RELATIONS. Application of antitranspirants resulted in decreased leaf water and osmotic potential at two DAT (Table 1). This decrease in water potential may be related to phytotoxic effects and not to transpiration. Hummel (1990) showed that both Vapor Gard and WiltPruf reduce the transpiration of impatiens. Normally, reduced transpiration causes an increase in water potential, rather than a decrease. Both dip treatments resulted in necrotic leaf spots and these phytotoxic effects may have contributed to the decrease in water and osmotic potential. Although there was little visible damage from the spray treatments, subtle effects may have affected water and osmotic potential in these treatments too. There were no significant differences in water or osmotic potential at 9 or 16 DAT. There were no statistically significant differences in pressure potential (a measure of leaf turgidity), although it tended to be higher in the control treatment than in the antitranspirant treatments at 2 and 9 DAT. There were no differences in shoot dry mass at 16 DAT (results not shown), when the experiment was ended.

Conclusion

Wax-based antitranspirants did not decrease transplant shock of impatiens seedlings in a greenhouse. Antitranspirants decreased growth rate, probably because of lower leaf photosynthetic rates, and caused necrotic spots on leaves and in some cases plant death. Water and osmotic potential was decreased by antitranspirants at 2 DAT, indicating that antitranspirants do not help to maintain a favorable water status of impatiens. Cultural practices in a greenhouse normally are aimed at preventing environmental stress by maintaining optimal water and fertility levels. Therefore, transplant shock is expected to be less severe in a greenhouse than under field conditions, which helps to explain why antitranspirants do not reduce transplant shock in impatiens in a greenhouse environment.

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Root Pruning and Soil Type Affect Pecan Root Regeneration

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ADDITIONAL INDEX WORDS. *Carya illinoensis*, transplant, taproot

SUMMARY. Taproots of 2-year-old 'Apache' seedling pecan [*Carya illinoensis* (Wang)] trees were pruned to 1 ft (30 cm), 2 ft (60 cm), or 3 ft (90 cm) in combination with wounding treatments consisting of no wounding, scraping through pericycle tissue on one or two sides of the taproot, or longitudinally splitting the taproot for about half its length. The trees were planted in a Port silt loam soil and a Teller sandy loam soil and grown without irrigation. At the end of the first and second growing seasons, top growth was measured, trees were dug and root system regrowth was evaluated. Tree root weight and number of roots per tree decreased with increasing taproot length.

The pecan tree has an aggressive taproot system best suited to deep alluvial soils. The taproot will penetrate the soil >6 ft (2 m) unless stopped by a water table or an impervious layer, e.g., rock. The taproot is dominant over other roots in the system and reestablishes itself when removed (Smith and Johnson, 1981). Taproot pruning to various lengths stimulates top growth, root branching and growth the first year. Root reestablishment occurs first at the cut surface (Smith and Johnson, 1981). Taproot pruning also increases leaf nutrient concentration (Sparks and Madden, 1977). Other researchers have reported no effect of root pruning on tree growth after 4 years (Wood, 1996) or on trunk weight, height, root depth, and number or weight of roots after 5 years

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(Laiche et al., 1983). Root regeneration occurs from the pericycle (Esau, 1977) and new branch roots must force their way through the cortex. Accelerated root regeneration at the cut surface is presumably due to exposure of the pericycle. The cut may also decrease resistance to branch root emergence. Research has not been conducted to determine if wounding through the pericycle without cutting off the taproot would stimulate lateral root formation. Likewise, the literature does not compare the effects of site on root regeneration in response to wounding of the pecan taproot.

The goals of this study were to determine if taproot wounding treatments in combination with pruning would affect branch root initiation in pecan and to evaluate soil effects on pecan tree root and shoot growth.

Materials and methods

Two-year-old ‘Apache’ seedling pecan trees were obtained from a commercial nursery for planting in March 1994. The test was established at the Oklahoma Pecan Research Station, Perkins, Okla., in Teller fine sandy loam soil (fine-loamy, mixed, thermic Udic Argiustolls) and at the Pecan Research Station, Sparks, Okla., in Port silt loam soil (fine-silty, mixed, thermic Cumulic Haplustolls). Port and Teller series soils were formed in thick deposits of old loamy alluvial sediment. Both are deep, well-drained and moderately permeable. Port soils range in slope from 0% to 1% while Teller soils slope from 0% to 5%. The Sparks site is generally less susceptible to drought but more susceptible to flooding and waterlogging than the Perkins site. Neither site was irrigated aside from hand watering to reduce loss the first year. The Sparks site received 30.7 inches (78.1 cm) and 41.1 inches (104.5 cm) of rainfall from March through October in 1994 and 1995, respectively, and was under water for ≈3 d in July of 1994 and May 1995. The Perkins site received 22.9 inches (58.1 cm) and 38.8 inches (98.5 cm) of rainfall from March through October of 1994 and 1995, respectively.

Trees were spaced 10 ft (3 m) × 20 ft (6 m). Treatments consisted of taproots cut to 1 ft (30 cm), 2 ft (60 cm), or 3 ft (90 cm) long in factorial combination with wounding treatments consisting of no wounding, scraping through pericycle tissue on one or two sides of the taproot, or longitudinally splitting the taproot about half its length. Immediately after application of treatments, trees were planted in 8 inches (20 cm) diameter auger dug holes to a depth such that the crown was at or within 2 inches (5 cm) above the final soil surface. Newly planted trees were watered to settle the soil. Each treatment was applied to nine trees, three replications of three trees, in a completely randomized design. During the growing season weed pressure was reduced by means of preemergence herbicide [(oryzalin)3,5-dinitro-*N*4,*N*4-dipropylsulfanilamide] and spot treatment with contact herbicide [(glyphosate) Glyphosate-isopropyl-ammonium]. After the first and second year (March 1995 and January 1996), one tree per replication was dug using a 30 inch (75 cm) diameter Vermeer TS30 spade. The trees were separated from the soil and primary lateral root length and dry weight as well as length of new shoot growth was measured and recorded. Number of primary lateral roots formed from the cut surface of each tree taproot was recorded at the end of the second growing season.

Data were analyzed by year using analysis of variance. If the interaction between taproot length and site or wounding treatment was significant, then the main effect of the related treatments and the interaction were pooled and trends within the nonrelated treatments were determined. Trend analysis was used for main effects of related treatments and Fishers F test or Duncan's multiple range test was used for main effects of nonrelated treatments (Snedecor and Cochran, 1971).

Results and discussion

There were similar survival rates between trees with the three taproot lengths at both sites (Table 1). Wounding treatment had little effect on tree survival (data not shown). The site by root length interaction effect on total shoot growth was significant both years. Total shoot growth was greatest from trees with 3-ft taproots at Perkins, while trees at Sparks produced more shoot growth from trees with 2-ft taproots in 1994 and from 1-ft taproots in 1995 (Table 1).

Trees at Sparks produced greater shoot and root weight than those at Perkins in each year. There was no significant difference in number of roots per tree between sites (Table 2).

Many factors, e.g., soil depth, soil structure, soil aeration, and plant nutrition are involved in root and terminal growth. Soil moisture stress, i.e., a period of dry weather during July through early September coupled with the lighter soil at Perkins and two periods of flooding in the heavier soil at Sparks, probably was a key factor in the results.

The number and weight of branch roots per tree decreased as taproot length increased (Table 3). Trees with 1 ft taproots produced more than twice as many roots per tree as those with 3-ft taproots. Lateral root formation is stimulated by auxin and other growth regulators (Esau, 1977) while lateral

Table 1. The effect of site and taproot length on pecan tree survival (1994), and total shoot growth during the 1994 and 1995 growing seasons.

Site	Taproot length (ft)	Survival (%)	Current season's shoot growth per tree (cm) 1994	Current season's shoot growth per tree (cm) 1995
Perkins	1	86	26	79
	2	64	21	67
	3	97	42	122
Sparks	1	97	68	310
	2	86	73	186
	3	86	65	223
Site × root length			*	*
Perkins, root				
L			*	NS
Q			NS	NS
Sparks root				
L			NS	**
Q			*	NS

*,**Significant at $P = 0.05$ or 0.01, respectively; L = linear, Q = quadratic.

Table 2. The effect of site on weight of shoots and primary lateral roots during two growing seasons, and the number of primary lateral roots per tree after the second growing season.

Site	Current season's shoot growth per tree (g)		Root wt per tree (g)		Roots per tree (no.)
	1994	1995	1994	1995	
Perkins	4	26	2	9	10
Sparks	11	64	14	18	9
Significance	*	*	*	*	NS

*Significant at $P = 0.05$.

Table 3. The effect of taproot length on primary lateral root weight per pecan tree during two growing seasons, and on the number of primary lateral roots per tree after the second growing season.

Taproot length (ft)	Root wt per tree (g)		Roots per tree (no.)
	1994	1995	
1	12	23	13
2	6	7	8
3	4	7	6
Linear	*	***	**
Quadratic	NS	*	NS

Significant at $P = 0.05$, 0.01, or 0.001.

root growth is inhibited by high concentrations of auxin (Westwood, 1993). Root number decreased with increasing taproot length (Table 3) while total shoot growth varied with site and taproot length (Table 1). Shoot growth from the Sparks site was greatest from 2-ft taproots in 1994 and from 1 ft taproots in 1995 (Table 1). Trees at the Perkins site, however, produced more shoot growth from longer taproot trees (Table 1) which had fewer branch roots (Table 3). This difference could have been due to soil differences, e.g., texture, aeration or water holding capacity, as suggested by Smith and Johnson (1981) or to auxin imbalance between the top and root. These determinations were beyond the scope of this experiment.

Similar to the findings of Wood (1996) taproot length did not affect shoot dry weight at either location (data not presented). As taproot length increased, the dry weight and number of roots produced decreased (Table 3).

Conclusions

Wounding of the taproot other than cutting to length was not beneficial. Pruning the taproot before transplanting a bare root pecan tree stimulates primary lateral root and shoot growth the first 2 years after transplanting. The ideal taproot length varies with site. In light-textured soils with potential for water shortage at shallow depths, longer taproots appear to be warranted. In heavier or well-irrigated soils, a taproot cut to ≈1 ft seems to be the best choice.

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Improving Bedding Plant Quality and Stress Resistance with Low Phosphorus

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Additional index words. drought, *Impatiens wallerana*, plant nutrition, postproduction quality, *Tagetes patula*, phosphorus

Summary. Bedding plants are frequently exposed to water stress during the postproduction period, resulting in reduced quality. We demonstrated that alumina-buffered P fertilizer (Al–P) provides adequate but much lower P concentrations than conventionally used in soilless mixes. When impatiens (*Impatiens wallerana* Hook. f. 'Impulse Orange') and marigold (*Tagetes patula* L. 'Janie Tangerine') plants were grown with reduced phosphorus using Al–P, P leaching was greatly reduced and plant quality was improved. Diameter of impatiens plants and leaf area of plants of both species were reduced by Al–P. Marigold plants grown with Al–P had more flowers and fewer wilted flowers. Flower wilting was also reduced for impatiens plants grown with Al–P. In marigold plants, roots were confined to a small volume beneath the drip tube in control plants, while roots of Al–P plants were well distributed through the medium. There was no obvious difference in impatiens root distribution. When plants at the marketing stage were exposed to drought, the Al–P plants of both species wilted more slowly than the conventionally fertilized controls. The reduced leaf area in both species

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